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EFFECTS OF FEEDING DISTILLERS GRAINS THROUGHOUT A YEARLING HEIFER BEEF PRODUCTION SYSTEM ON MEAT QUALITY ATTRIBUTES AND EFFECTS OF OMNIGEN – AF WITH RACTOPAMINE HYDROCHLORIDE ON ANIMAL PERFORMANCE AND BEEF CARCASS CHARACTERISTICS OF FEEDLOT STEERS

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By

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ABSTRACT: Heifers (n = 229; 225 kg ± 2) were used in a 2 x 2 x 2 factorial to determine the effects of longterm exposure to corn distillers grains plus solubles (DGS) on meat quality characteristics. Factors included supplementing 0.91 kg (LW) or 2.3 kg (HW) modified DGS (MDGS) while grazing corn stalks; 0.6% BW dry DGS (SS) daily or none (NS) during summer grazing; and finishing diet containing 40% wet corn gluten feed (CGF) or 40% MDGS (DGF) on a DM basis. An interaction was observed within CGF for discoloration, with SS increasing discoloration 30%; but no differences between SS or NS from DGF cattle. Discoloration scores for DGF increased compared to CGF d 6 - 7 and d 4 - 6 for steaks aged 7 and 21 d, respectively. Supplementing with DGS did not further reduce the color stability of retail beef of DGF finished cattle; however, DGS supplementation prior to finishing can affect beef quality when DGS are not included in the finishing diet. In the second study, crossbred steers (n = 336) were utilized in a 2 x 3 factorial evaluating duration of OmniGen – AF supplementation (0, 28, or 56 d) at 4 g / 45.5 kg BW and supplementation of ractopamine hydrochloride (RAC) at 300 mg/ steer daily for the last 28 days of finishing or no supplementation. No Omnigen – AF by RAC interaction or OmniGen –AF effects were observed for any feedlot performance or

carcass characteristics measured. Supplementing RAC increased ADG 0.5 kg, increased FBW 10.0 kg, and increased LM area 0.9 cm^2 compared to NORAC.

Keywords: Beef, Discoloration, Distillers, OmniGen – AF, Ractopamine hydrochloride

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DEDICATION

This thesis is dedicated to all past, present, and future friends and family members.

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CHAPTER I: INTRODUCTION

Distillers grains plus solubles (DGS) are commonly fed as an economic energy source replacing corn in beef cattle diets leading to increased ADG, improved G:F, and reduced costs of production (Larson et al, 1993; Ham et al., 1994; Klopfenstein et al. 2008). A portion of the corn oil present in DGS may be protected from rumen biohydrogenation resulting in increased fat digestibility and concentration of polyunsaturated fatty acids (PUFA) reaching the duodenum (Vander Pol et al., 2009).The increased concentration of PUFA reaching the duodenum causes an increase in the amount of PUFA that is absorbed. As the level of DGS inclusion in finishing diets increases there is a linear increase in PUFA concentration within the beef (Koger et al., 2010; de Mello et al., 2012).. The increased PUFA results in greater oxidation potential and decreased color stability of the retail beef shortly after being placed in the retail case (Koger et al., 2010; de Mello et al., 2012). Decreased color stability is caused by the PUFA being more readily oxidized than the monounsaturated or saturated fatty acids. The increased oxidation results in a decreased retail shelf-life and a potential loss of retail value. Sherbeck et al. (1995) estimated that 2 to 20% of fresh beef is discounted or discarded due to loss of desirable color in U. S. retail stores.

Supplementing DGS to cattle backgrounded on cornstalks or grazing pasture throughout a yearling beef production system is economically beneficial (Gillespie, 2013). However, supplementing DGS would increase the total amount of dietary PUFA to which the animal is exposed to throughout the production system if DGS were also included in the finishing diet. There is currently little research evaluating this effect on

the quality of retail beef. Buttrey et al. (2012) evaluated the effects of supplementing dried DGS to stocker cattle grazing winter wheat pasture prior to feedlot entry and reported that DGS supplementation increased the PUFA concentrations in beef, but no further meat quality analyses were performed.

The objective of the first study was to determine if the supplementation of DGS during the backgrounding and grazing periods was cumulative with DGS finishing diet inclusion increasing the oxidation and discoloration of steaks resulting in reductions in shelf-life of beef.

Ractopamine hydrochloride (RAC; Elanco Animal Health; Greenfield, IN) is a beta-adrenergic agonist administered to beef cattle via feed supplementation during the last 28 – 42 days of the finishing period at a rate of 8.2 to 24.6 g/ton and provide 70 to 430 mg/ animal/ daily with no withdrawal period (FDA, NADA 141-221, 2003). Beta – adrenergic receptors are membrane bound receptors that belong to the large family of G-protein coupled receptors and are the binding site for the catecholamines epinephrine and norepinephrine (Beermann, 2002; Mills, 2002a). The binding of ractopamine hydrochloride to the receptor site elicits a response that causes an increase in the proportion of lean muscle mass relative to body fat (Beermann 2002; Mills 2002a). These compounds are fed during the final stages of finishing, just prior to harvest, where the animal is nearing maturity. As the animal reaches maturity, the rate of muscle deposition slows, but the rate of fat deposition increases. Supplementing cattle with ractopamine hydrochloride reduces the rate at which body fat is deposited, allowing for continued increase in the proportion of muscle growth through increasing muscle fiber hypertrophy

(Beermann, 2002; Mills 2002a). Supplementing cattle with ractopamine hydrochloride during the final 28-40 days of the feedlot finishing period increases ADG, G:F, dressing percentage HCW, and FBW, while having little to no impact on DMI, 12^{th} rib fat thickness or marbling characteristics (Gruber et al. 2007; Quinn et al., 2008; Vogel et al., 2009; Boler et al., 2012; Bittner et al., 2014).

However, antidotal reports have surfaced with claims of cattle experiencing a suppressed immune system or impaired mobility due to beta – agonist supplementation. OmniGen – AF is commercial feed additives that provides a supplemental source of B-complex vitamins and live yeast cells that are marketed as providing an immune system boost to the animal (Prince Agri Products, Inc., 2006.). Georges et al. (2005) reported that supplementation of OmniGen – AF at 1% of the diet DM increased BW gain (1.9 to 2.8 g / hd / d), and G:F by day 14, while also observing a six fold increase in neutrophil L – selectin, a measure of immune function in rats not immunosuppressed by dexamethasone injections. Furthermore, in lambs that experienced a pathogen challenge (*Aspergillus fumigatus*; > 1 million spores/ g), OmniGen – AF supplementation increased concentrations of both L – selectin and IL-1β (Wang et al., 2004). Chapman et al. (2005) evaluated the effects of supplementing OmniGen – AF at 56 g / cow daily in Holstein cows on milk production and persistence of milk yield during a 60 day field trial. Daily milk production was increased from 33.4 to 34.1 kg/ cow daily by including Omnigen – AF to the cow's final diets while also increasing the persistence of milk yield. In a 44 day feedlot receiving study performed by Reuter et al. (2007), the supplementation of OmniGen – AF and Sucram C – 150 (0.68 and 26.7% supplement DM, respectively,

replacing ground corn) included at 3.0% (DM basis) of the diets had no effect on heifer growth performance (ending BW, ADG, DMI, and G:F) during the receiving period or feedlot growth performance (HCW, FBW, and ADG), along with no effects on 12th rib fat depth, LM area, USDA Yield Grade, and KPH %. However, in several studies where feedlot cattle were exposed to an endotoxin challenge (lipopolysaccharide, LPS), researchers reported an ability of OmniGen – AF to prime the immune system prior to the LPS challenge which allowed the cattle to a display stronger acute phase response to the LPS challenge while preserving energy stores in the body (Burdick 2012a, Vann 2012, Burdick Sanchez 2014a).

The objectives of the second study were to evaluate the effects of supplementing Omnigen – AF during the final 0, 28, or 56 days of the feedlot finishing phase with or without supplemented RAC on steer feedlot performance, carcass characteristics, and the change in body composition over the final 56 days via ultrasound imaging.

CHAPTER II: REVIEW OF LITERATURE

CORN MILLING

Corn milling is processing corn grain into a desired product or isolating and separating the valuable components of the grain. Corn milling is accomplished through one of three common methods termed dry grind ethanol, wet milling, dry milling which utilize different processes to obtain distinctly different final products. The different processes used also produce different byproducts that are then available for feeding cattle (Stock et al. 2000).

Dry Grind Ethanol Process. The dry milling process produces 67% of the fuel grade ethanol in the United States, making it the most common method of producing ethanol (Bothast and Schlicher, 2005; Kwiatkowski et al., 2006). The high prevalence of dry milling plants is due mainly to the efficiency advantage in using fewer steps for the conversion of starch to glucose which is then fermented into ethanol (Bothast and Schlicher, 2005). This process can be summarized in five main steps described by Bothast and Schlicher (2005) as grinding, cooking, liquefaction, saccharification, and fermentation.

Corn is delivered to the milling facility where it is placed in storage before processing. The first step is cleaning of the grain using screens and blowers to remove foreign material, broken kernels, and various other fine particles (Kwiatkowski et al., 2006). Corn is then ground using a hammer mill to form a coarse flour that is mixed with water to create a “mash” (Bothast and Schlicher, 2005). The mash mixture is cooked by being heated to over 100°C for several minutes with a jet cooker following the addition

of a thermostable alpha-amylase and the regulation of the pH to 6.0 (Bothast and Schlicher, 2005). The heat and force of the jet cooker physically expose the starch molecules, allowing the alpha-amylase to randomly hydrolyze the alpha 1-4 bonds to produce soluble oligosaccharides, called dextrins (Bothast and Schlicher, 2005; Kwiatkowski et al., 2006). The temperature is then reduced to 80-90°C and more alpha-amylase is added to the mash prior to being agitated to liquefy the mash. The liquefaction step gelatinizes the starch and continues to reduce the length of the starch polymers, producing more dextrins. The pH of the mash is then reduced to 4.5 with the addition of sulfuric acid and the temperature is reduced to 61°C (Kwiatkowski et al., 2006). Glucoamylase is added to act on the alpha 1-4 bond of non-reducing end of maltose and other oligomers, producing glucose molecules, while the alpha 1-6 branches are cleaved by pullulanase (Bothast and Schlicher, 2005; McAloon et al. 2000).

Some ethanol plants use a process called saccharification which converts dextrins into glucose. Saccharifcation reduces the amount of glucoamylase required to produce glucose, but takes at least 5 h (Bothast and Schlicher, 2005; Kwiatkowski et al., 2006). The glucoamylase can remain active throughout the fermentation process as long as free dextrins remain in the mash (Kwiatkowski et al., 2006). Since glucoamylase remains active, many plants have combined the saccharification and fermentation process. Combining these steps takes advantage of increased energy efficiency, reduces the possibility of any microbial contamination, and reduces the osmotic stress the yeast would experience if placed in a concentrated glucose environment if the processes were to remain separate (Bothast and Schlicher, 2005).

After saccharification, the mash is moved to fermentation vessels where it is cooled to 32°C; yeast is added and then the mash is fermented for 48-72 h (Bothast and Schlicher, 2005). Yeast converts the glucose to ethanol and carbon dioxide, and the carbon dioxide is released as a by-product (Kwiatkowski et al., 2006). The carbon dioxide given off during fermentation has monetary value and is commonly recovered with a carbon dioxide scrubber. Carbon dioxide is sold for use in the food processing industry as a preservative and for carbonating beverages, the chemical industry for production of chemicals and polymers, and even as a feedstock for algal biofuel production (Bothast and Schlicher, 2005; Kwiatkowski et al., 2006; Xu et al., 2010).

Following fermentation, the ethanol can be recovered. Recovery is accomplished by first transferring the mash to a distillation column where the mash is heated to allow the more volatile ethanol to vaporize, leaving the water and solids behind. This process takes advantage of the fact that ethanol vaporizes at 78°C compared to 100°C for water (Bothast and Schlicher, 2005). The heat of vaporization alone does not produce a pure ethanol product. Instead the distillate is further processed using a rectifier that removes 99% of the ethanol, a stripper that removes additional water and feeds the distillate back to the rectifier, and molecular sieves that capture the last bit of water generating a 99.6% pure ethanol product (Kwiatkowski et al., 2006). A 5% denaturant, typically gasoline, is then added to the ethanol product to prevent human consumption (Bothast and Schlicher, 2005; Kwiatkowsi et al., 2006).

The remaining mash exits out the bottom of the distillation column. The mash is mostly water, containing about 15% solids which contain all the protein, oil, and fiber

from the original grain source which were not fermented into ethanol. This product is termed “whole stillage” (Bothast and Schlicher, 2005; Kwiatkowski et al., 2006). The whole stillage is then centrifuged to remove a portion of the water producing a 35% dry matter product called wet distillers grains and the liquid fraction called “thin stillage” (Kwiatkowski et al., 2006). Bothast and Schlicher (2005) explain that a percentage (15-30%) of the thin stillage is recycled and fed back into the liquefaction process. The remaining thin stillage is further dried to 35% dry matter distillers solubles through the use of evaporators so water can be recycled back through the plant. Numerous plants have now begun to increase profit potential through the capture and sale of the corn oil present in the solubles. A portion of the oil that is not bound to fiber particles is removed via centrifugation of the solubles and destined for biodiesel production (Cantrell and Winsness, 2009). Kwiatkowski et al. (2006) explain that these solubles are then added back to the wet distillers grains producing wet distillers grains plus solubles, a 35% DM product. The wet distillers grains plus solubles can be further dried to produce a 45-50% DM product termed modified distillers grains plus solubles or a 90% DM product called dry distillers grains plus solubles.

Wet Milling Process. The wet milling industry results in different end products than ethanol fuel produced by the dry milling industry. The wet milling industry aims to separate and isolate the four main components (starch, fiber, protein, and germ) of the corn kernel through a procedure that involves grain steeping, germ recovery, fiber recovery, protein recovery, and finally starch purification (Rausch and Belyea, 2006). Similar to the dry grind process, the corn needs to be screened and cleaned of foreign

materials that could affect the quality of the final products prior to being processed. This is especially important in wet milling since most products are intended for human consumption (Stock et al., 2000).

The first step of the wet milling process is steeping the corn by soaking in a dilute sulfur dioxide solution for 24-48 hours (Rausch and Belyea, 2006). Steeping aids in separation of the components of the kernel by softening the protein matrix, increasing moisture content to 45% and removing any solubles through the steepwater which is dried to 40 to 50% dry matter, generating steep liquor (Rausch and Belyea, 2006; Ramirez et al., 2008). The corn then passes through a coarse grind before the germ is removed through the use of a series of hydrocylcones where germ, having a lower density than the other corn components, is carried out with overflow to be collected, washed, and dried. The rest of the slurry passes out the bottom of the hydrocylcones and continues through the separation process (Ramirez et al., 2008).

The degermed slurry then passes through a series of screens and washes to remove the fiber or bran that is combined with the steep liquor to produce corn gluten feed that can be sold either wet (40-60% DM) or dry (90% DM) with variations across plants in nutrient profiles due to proportions of bran, distillers solubles, germ meal, and corn screenings added (Stock et al., 2000; Rausch and Belyea, 2006). Due to the removal of the germ portion, that contains the corn oil, of the corn kernel the distillers solubles produced by the wet milling industry do not have a fat content as high as the distillers solubles from the dry milling industry (Stock et al. 2000).

The gluten and starch portions are then separated in centrifuges. The lower density gluten is carried off in the overflow and the higher density starch fraction passes out below to be purified further with a series of hydrocylcones to a final purity of greater than 99% starch (Rausch and Belyea, 2006; Ramirez et al., 2008). The purified starch is then sold or undergoes further processing to produce a wide variety of products including high fructose corn syrup, energy for microbial fermentations, or fermented to produce fuel grade ethanol.

The gluten fraction is concentrated by removing water using a centrifuge, and a rotary vacuum belt filter before finally dried to achieve a dry matter of 90% termed corn gluten meal. Corn gluten meal is high in protein and low in fiber, thus of high demand in the pet food and poultry industries (Stock et al., 2000; Rausch and Belyea, 2006).

FEEDING DISTILLERS GRAINS

Composition of Distillers Grains. Corn grain contains 9.80% protein, 4.30% fat, and 71.7 % starch (NRC, 1996). Belyea et al. (2004) sampled corn grain being processed at a dry mill plant on a monthly basis from 1997 to 2001 and found significant variation in the corn's nutrient profile. Differences found however, were small in terms of biological sense, with ranges of 8.94 to 9.23% protein, 4.04 to 4.36% fat, and 70.6 to 71.8% starch, with mean averages of 9.10% protein, 4.21% fat, and 71.4% starch, which agree with those reported in the NRC.

The dry mill process utilizes the starch fraction for the production of ethanol, and this removal of starch causes a three-fold increase in the nutrient content of distillers

grains (DGS) over that of the corn grain used in the dry milling process (Stock et al., 2000). Belyea et al. (2004) reported nutrient values of dried DGS sampled from a single plant from 1997-2001 of 28.3 to 33.3% protein, 10.9 to 12.6% fat, 9.6 to 10.6% fiber, but only 4.7 to 5.9% starch with means of 31.3% protein, 11.9% fat, 10.2% fiber, and 5.1% starch. The values reported by Belyea et al. (2004) illustrate the three fold increase in nutrition concentration in DGS following starch fermentation. Just as with corn grain, there is variability in the nutrient profile of DGS not only within a given plant but also across plants that could be caused from corn hybrid used, amount of distillers solubles added back to the DGS, and the efficiency of the starch fermentation (Spiehs et al., 2002; Buckner et al., 2011). Buckner et al. (2011) sampled DGS from six Nebraska ethanol plants and reported ranges of 30.1 to 32.2% protein, and 10.9 to 13.0% fat, which were higher than the ranges of 28.7 to 31.4% protein, and 10.2 to 11.7% fat reported by Spiehs et al. (2002). The across plant variability has since increased with the advent of the removal of corn oil from the thin stillage as described in the dry milling process as plants are now capable of removing about a third of the oil that was originally present.

Effects of Distillers Grains in Feedlot Diets. Cereal grains, especially corn, included in cattle diets are considered the second highest input cost for beef production, behind only the cost of the animal itself. The incorporation of DGS into beef finishing diets as a source of both energy and protein is an effective means of reducing the costs of finishing cattle (Larson et al, 1993; Ham et al., 1994; Klopfenstein et al. 2008). This reduced unit cost of production is attributed to the higher energy value of DGS compared to the corn it replaces and being a cheaper protein source than traditional sources of protein. Stock et

al. (2000) explained that this greater energy value could be attributed to a combination of factors including reduced acidosis, increased energy utilization, and any yeast end products remaining after ethanol fuel production. Vander Pol et al. (2009) further studied this increase in energy during a metabolism trial and concluded the increased energy may be due to a decrease in the acetate: propionate ratio and a greater fat digestibility due to more unsaturated fatty acids entering the duodenum from DGS compared to corn.

While the feeding value of DGS is greater than corn, it is dependent on the dry matter content of the DGS, the level of inclusion of DGS in the diet and how corn in the diet is processed (Corrigan et al., 2009; Bremer et al., 2011).

Distillers grains are commonly sold in three forms: wet, modified, or dry with average dry matter contents of 35, 50, and 90% respectively. The process of drying DGS to create modified or dried DGS decreases the energy value of DGS in finishing diets (Ham et al., 1994; Nuttelman 2013). Ham et al. (1994) compared corn control diet and reported G:F of 0.133, 0.158, and 0.146 for control, wet, and dry DGS diets, respectively. The inclusion of DGS in the study increased G:F, but the increase was not as great for the dry form of DGS in comparison to the wet form. Similarly, in a study by Nuttelman et al. (2013), steers fed wet, modified, or dry DGS had similar ADG, but differences in DMI resulted in differences in G:F. Efficiency was the greatest for steers fed wet, intermediate for modified and lowest for dry DGS. In a meta-analysis of 20 studies that fed wet DGS and 4 studies each for modified and dried DGS, Bremer et al. (2011) determined the feeding value of DGS at 0 to 40% inclusion in finishing diets replacing corn. Steer ADG was not different for the different DGS forms; however, DMI

was greatest for steers receiving dried, intermediate for modified, and lowest for steers receiving wet DGS. The similar ADG, but different DMI among DGS type caused increased moisture content of DGS to improve feed efficiency so that the greatest G:F was for steers receiving wet, intermediate for modified, and lowest for steers receiving dry DGS, but all greater than corn control diets. Feeding value was determined by the increased G:F of diets containing DGS compared to the control diets divided by the inclusion of distillers in the diet and expressed as a percentage of energy in corn. Feeding value of DGS increased as moisture content increased with values of 112, 124, and 150% energy of corn at 10% dietary inclusion for dry, modified, and wet DGS. Feeding values from Ham et al. (1994) can be calculated using the same method to attain values of 147 and 124% for wet and dry DGS at 40% the diet (DM basis). Drying DGS increases storage life while reducing transportation costs of the DGS. However, the increased energy content of the greater moisture forms could potentially make wet or modified DGS more economical depending on feedlots proximity to ethanol plants.

While dry matter content may be the largest determinate of the feeding value of DGS, dietary inclusion also plays a significant role in determining feeding value. In the meta-analysis performed by Bremer et al. (2011), modified and wet DGS feeding value decreased from 128 to 117% and 150 to 130% with increased dietary inclusion from 10 to 40%, respectively. Feeding value for dry DGS was 112% the value of corn across all dietary inclusion levels. High inclusions (50-60%) of full fat (12-15% fat) DGS inclusion could lead to negative effects on diet digestibility and DMI (Zinn 1989; Coppock and Wilks, 1991; Bock et al., 1991). The reduced digestibility coupled with the reduced DMI

would potentially reduce the amount of energy the animal consumes, causing a reduction then in ADG and G:F.

Due to the high prevalence of ethanol plants in the Midwest states and overall lack of ethanol plants in the Southern states, most of the research conducted with DGS was performed by replacing dry-rolled or high moisture corn or even a blend of these two corn processing methods. It's important to note that feeding a blend of high moisture and dry rolled corn increases the energy content of the corn blend over feeding the individual corn processing methods separately (Stock et al. 1987). The increased energy content of the blend would result in reduced response to dietary DGS inclusion. However in the southern states, cattle feeders typically utilize steam flaking for corn processing to further enhance feed efficiency. The use of steam flaking changes the site and the extent of starch digestion from 76.2 and 96.1% for ruminal and total tract digestion, respectively, in dry rolled corn to 89.6 and 99.8% in steam flaked corn (Cooper et al. 2002). It has been well established that increasing the degree to which corn is processed increases the efficiency with which starch within the corn kernel is utilized, thus resulting in increased G:F in finishing diets without the inclusion of DGS (Owens et al., 1997). The response to inclusion of DGS in diets containing steam flaked corn; however, is different than the response experienced with other corn processing methods. In dry rolled or high moisture corn based diets, the inclusion of DGS increases ADG and G:F due to the greater energy content present in DGS. However, in steam flaked corn diets, the inclusion of distillers does not have the same positive effects on ADG, G:F, and final BW (Vasconcelos, et al., 2007; Corrigan et al., 2009; Luebbe et al., 2012). In the study by Corrigan et al. (2009)

steers were fed wet DGS at 0, 15, 27.5 and 40% inclusion (DM basis) in dry rolled corn, high moisture corn, and steam flaked corn based diets. Steer ADG and carcass adjusted final BW increased linearly within dry rolled corn diets, increased quadratically with high moisture corn, but decreased quadratically with steam flaked corn as wet distiller's grains inclusion increased. Steer G:F increased linearly in both the dry rolled (0.163 to 0.185) and high moisture corn (0.183 to 0.194) based finishing diets as DGS was increased from 0 to 40% (DM basis). However, there was no effect of DGS inclusion on G:F in the steam flaked corn diet (0.182, 0.186, 0.182, 0.183 for 0, 15, 27.5, and 40% inclusion respectively). Even higher concentrations of DGS (0, 15, 30, 45, and 60%; DM basis) were fed in the study by Luebbe et al. (2012) in steam flaked corn based diets. Steer ADG, final BW, and G:F linearly decreased as greater amounts of DGS were included in the finishing diet.

There are several minerals that are commonly considered when feeding DGS, including sulfur and phosphorous. Sulfur is a concern because elevated levels of sulfur (>0.4% of the diet; DM basis) are potentially toxic to cattle leading to polioencephalomalacia, which is a central nervous system disorder (NRC, 2003). However, other authors (Nichols et al., 2013, Sarturi et al., 2013a, Sarturi et al., 2013b) have suggested that greater levels of dietary sulfur can be fed (<0.6% of the diet; DM basis). Sarturi et al. (2013b) proposed the concept of ruminal available sulfur which demonstrates that not all sources of sulfur (organic and inorganic) are readily converted to hydrogen sulfide in the rumen. The authors demonstrated that organic sources of sulfur are commonly proteins that undergo degradation and deamination. The degradation and

deamination of these organic sources of sulfur are responsible for up to 0.35% of the sulfur concentration in DGS (Klopfenstein et al., 2008). Furthermore, Nichols et al. (2013) reported the relationship between polioencephalomalacia and sulfur could be altered through inclusion of roughage in feedlot finishing diets that contain DGS. Phosphorous levels can also be detrimental to cattle if there is an imbalance in the calcium to phosphorous ratio <1.1:1 for prevention of urinary calculi (NRC, 1996). However, the often overlooked concern with phosphorous is the environmental issue it presents in feedlot runoff. According to the NRC (1996) the sulfur content of corn grain is 0.11% and phosphorous is 0.32%. During the production of DGS the content of these minerals is increased three fold due to the removal of starch as described previously. Thus, phosphorous concentration of DGS is 0.8 to 0.9%. However sulfuric acid is used in the production process (Kwiatkowski et al. 2006) for reducing pH and cleaning of equipment and this sulfur ends up in the DGS, increasing the sulfur concentration from 0.7 to 1.0% (Buckner et al., 2011). Much of the variability in the sulfur concentration is due to the amount of sulfuric acid used and the emphasis the dry mill plant places on the value of the DGS as either a by-product or co-product.

Effects of Distillers Grains in Forage Situations. The vast majority of the calves born in the United States beef herd are born in the springtime, creating a large supply of weaned calves in the fall. If all these calves were placed in a feedlot and put on a finishing diet, they would all be slaughtered in roughly the same time frame of May to June the following year when they are 14-16 months of age. Such a system would be very inefficient and detrimental to a beef industry that aims to provide a constant supply of

consistent quality beef to consumers year round. Therefore, sorting cattle into different marketing programs (calf-fed, short yearling, long yearling) is beneficial. Sorting the calves into common BW groups allows producer to effectively manage BW variation to increase calf performance and profit potential (Griffin et al., 2007; Folmer et al., 2008; Adams et al., 2010).

Calf-feds are those calves that were purchased in the fall and placed directly into the feedlot for finishing where they would be harvested at 14-16 months of age. Calf-feds are typically the larger, older calves at fall, thus making them ideal candidates for being stepped up onto a finishing diet immediately after weaning, without the risk of overweight carcasses if calf – feds had been placed in a long yearling system. The lighter, smaller framed calves are commonly placed in one of the yearling systems to allow them to be grown for a period of time before being placed in the feedlot (Vieselmeyer 1993). Increasing initial BW of the small framed calves using a yearling system allows these calves to achieve desired carcass weights compared to the light carcass weights that would have otherwise been observed in a calf – fed system. This is beneficial because weight is the primary determinate of profitability in beef production (Tatum et al., 2006). Short yearlings are calves that are grown throughout the winter months in a backgrounding program prior to being placed in a feedlot. The winter backgrounding program can use a wide range of different methods to effectively grow calves such as grazing corn stalks, winter wheat pastures, or being placed on a high roughage grow diet in a dry lot pen. Following the winter backgrounding phase, short yearlings would enter the feedlot to be stepped up onto the finisher for harvest at 17 – 20 months of age. The

long yearlings would next go to grass pastures until they would enter the feedlot in late summer or fall and harvested at 20 – 22 months of age. During these growing phases, calves are partially restricted compared to if they were in a feedlot. However, once in a feedlot, these calves will compensate for the nutrient restriction and experience an increased ADG during finishing over the calf-feds. Distributing a year's calf crop across a production year allows producers to target different seasonal markets within the year to potentially achieve a higher price for calves, yearlings or finished cattle (Griffin et al., 2007; Adams et al., 2010). Folmer et al. (2008) evaluated different management strategies (targeted ADG, use of implants and ionophores, and sorting) for yearling beef production and reported that differences in steer performance and overall profitability can be impacted during each segment of the production cycle and that marketing goals ought to dictate management practice imposed.

Feeding DGS as either a supplement to calves grazing forage or included in a mixed high roughage growing diet has become popular with the increased availability of DGS. Due to the removal of starch during ethanol production and subsequent concentration of the highly digestible fiber and protein, DGS supplementation is an excellent source of supplemental protein and energy for calves on a forage based diet. Possibly one of the most significant advantages of using DGS as protein supplement is the ability to pair it with cheaper, low- quality forages, but balancing nutritional requirements with the nutrient dense DGS. In a forage situation, DGS initially were used as a protein supplement to meet the calves' metabolizable protein (MP) requirement. Folmer et al. (2008) reported steers managed to a lower targeted ADG through

supplementing 2.27 kg/ d of wet corn gluten feed to meet steers' MP requirements only while being wintered on corn stalk residue were more profitable at that time than a more intensive wintering system using growth promoting implants and supplementing 2.73 kg/d wet corn gluten feed when steers were retained through the feedyard. While wet corn gluten feed is a different corn milling by-product, the mechanism of meeting the calves' MP requirement to achieve increased forage efficiency is the same.

Higher concentrations of DGS supplementation, however, can be used as an energy source to replace or extend the available forage resources while providing even greater BW gains (Gustad et al., 2006; MacDonald et al., 2007; Greenquist et al., 2009). Gustad et al. (2006) evaluated supplementation of dried DGS to steer being wintered on corn stalk residue from 0.68 to 2.90 kg/ steer daily in 0.44 kg increments. Steer ADG increased quadratically from 0.40 to 0.80 kg when increasing dried DGS supplementation from 0.68 to 2.90 kg/ daily, respectively. The authors also supplemented dried DGS at the same supplementation amounts to calves being fed 70.9% brome hay and 29.1% sorghum silage growing diet control for the grazed corn stalk residue. The TDN of the growing diet was 59% which is comparable to the corn stalk residue that averaged 55% TDN during the grazing period. Steer ADG for those fed the growing diet ranged from 0.84 to 1.07 kg while DMI decreased from 5.02 to 3.69 kg/ d. Considering the comparable TDN values for the corn stalk residue and the growing diet, the authors proposed that stocking rates could be increased 27% by increasing supplementation of dried DGS from 0.68 to 2.90 kg / d. A 2 year study evaluating the use of DGS supplementation to calves being wintered on cornstalks, followed by supplementation while grazing summer pasture prior

to feedlot finishing was performed by Gillespie (2013). The authors reported that heifers consuming 2.3 kg/ d (DM basis; HI) of modified distillers during the winter corn residue grazing averaged 41.6 kg greater BW following winter backgrounding than heifers being supplemented 0.91 kg/ d (DM basis; LO) to meet MP requirements. Heifers were then placed on summer pasture where heifers received dried DGS supplementation at 0.60% of BW (SUP) or no supplementation (NO SUP). In year 1 of the study, the authors reported a winter by summer supplementation interaction ($P = 0.07$) levels for heifer ADG during summer grazing with heifers that received the LO, SUP treatment having the greatest ADG (0.88 kg/ d) but the least ADG for heifers receiving the HI, NO SUP (0.53 kg/ d), indicating that heifers being supplemented DDGS to meet MP requirements during the winter compensated during summer pasture grazing with DGS supplementation. During the feedlot finishing phase; however, heifers that received HI, NO SUP compensated for the nutrient restriction during the grazing period compared to the heifers that received the HI, SUP treatment. Overall heifers that received the HI, NO SUP treatment had the greatest HCW (375 kg) while heifers that received the LO winter supplementation had the least HCW (343 and 348 kg for LO, NO SUP and LO, SUP, respectively), with the HI, SUP being intermediate at 361 kg. Thus, supplementation of DGS to cattle consuming high forage growing diets improves ADG, G:F, and allows for increased stocking densities or extends available forage resources by replacing a portion of the forage in the daily diet the animal would otherwise consume.

EFFECTS OF FEEDING DISTILLERS GRAINS ON BEEF QUALITY

The increased replacement of cereal grains with distillers grain in feedlot diets has been an effective means of reducing the cost of feedlot production and is widely used in the industry. The large utilization of this byproduct of ethanol production has drawn significant interest as to its effects on beef quality. Therefore, impacts of DGS use in beef diets will be reviewed.

Effects on Yield and Quality Grades. Yield grades are estimates of the amount of boneless, closely trimmed retail cuts that can be sold from a beef carcass. Quality grades are considered predictors of palatability and are determined following evaluation of animal maturity, distribution and amount marbling, firmness, and the color and structure of the lean (Aberle et al., 2001). Cattle are typically marketed for slaughter when it is estimated that 12th rib fat depth averages 1.3 cm. The grading of carcasses allows for the standardization of retail beef in terms of quality to the eventual consumer. The inclusion of DGS has no effect on 12th rib fat thickness, yield grade or quality grades (Larson et al., 1993; Ham et al., 1994; Lodge et al., 1997; Vander Pol et al., 2009). Furthermore, de Mello et al. (2012b) showed that inclusion of modified DGS up to 50% (DM basis) did not affect marbling attributes. However, Koger et al. (2010) reported that carcasses from cattle fed either 20 or 40% (DM basis) DGS had increased fat thickness, increased yield grades, and reduced the percentage of carcasses receiving yield grades 1 and 2 compared to a corn control diet. Koger et al. (2010) concluded cattle fed DGS may need to be marketed sooner. The need for reduced days on feed to reach the target market endpoint

echoes the increased energy concentration of DGS compared with corn, resulting in an increased rate of gain to which an animal reaches a targeted fat thickness.

Effects on Beef Color. The most important aspect of beef sales is its visual appearance and how it relates to consumer perception of quality and freshness (Faustmann and Cassesns, 1990; Killinger et al., 2004). The color of beef is a result of the pigments hemoglobin and myoglobin. Hemoglobin is the pigment of blood while myoglobin is the pigment of muscles. Myoglobin consists of a globular protein and a heme ring. Myoglobin will account for 80 - 90% of the pigments in beef following exsanguination. Beef color is primarily dependent on the oxidation state of the iron within the heme ring which affects the ability of myoglobin to interact with other molecules. When iron is in the reduced oxidative state, iron is capable of interacting with either water forming deoxymyoglobin, or with oxygen forming oxymyoglobin. Deoxymyoglobin is the purple pigment associated with uncut or vacuum packaged beef in an absence of oxygen. Oxymyoglobin is the pigment associated with the bright cherry red color of beef and develops after 30 to 45 minutes of exposure to air. However when iron is in the oxidized form, myoglobin is oxidized into the metmyoglobin pigment that is responsible for the brown color of oxidized beef (Aberle et al., 2001). The oxidation of lipids within beef can initiate the oxidation process of myoglobin into metmyoglobin (Hur et al., 2003). The products of lipid oxidation of the unsaturated fatty acids are highly reactive radicals that have the potential to oxidize the iron contained in the heme ring of myoglobin, forming metmyoglobin (Faustman et al., 2010).

Color scores for meat products are commonly assessed using either subjective or objective methods. Subjectively, visual color scores can be appraised by a trained panel of individuals that evaluate the percent of the meat product surface that has discolored. Objectively, color coordinate values of L* (brightness, 0 = black and 100 = white), a* (redness/ greenness, positive values = red negative values = green), and b* (yellowness/ blueness, positive values = yellow and negative values = blue) can be measured using a spectrophotometer and averaging multiple light reflectance measures across the surface of a meat product (Gill et al., 2008).

A linear increase in the inclusion of distiller grains in beef finishing diets results in a proportional increase in discoloration of beef (Gill et al., 2008; Depenbusch et al., 2009; de Mello et al., 2012a). de Mello et al. (2012a) reported that after 7 days of simulated retail display, strip loins steaks from steers finished on diets containing 15 and 30% wet DGS had a lower a* values, thus were less red in color, than from steers finished on a corn control diet. The authors noted as soon as day 3 of retail display, tenderloin steaks from steers finished using the wet DGS diets had lower a* values. Furthermore, the authors reported that in top blade steaks, the 30% wet DGS finishing diet produced steaks that were less in a* value during the entire retail case display period. Considering that ethanol plants can use a variety of grains for ethanol production, thus producing different forms of DGS, Gill et al. (2008) evaluated the inclusion of either corn or sorghum based DGS at 15% inclusion (DM basis) in steam flaked corn based diets, in both the dry and wet forms of DGS. The authors reported no treatment or treatment by time interactions in visual color appraisal during the 7 day simulated retail display;

however, objective color coordinates effects were observed. Cattle were harvested in two different groups, with slight differences observed in color measures across harvest date. During the first harvest period, steaks from steers fed corn based DGS had greater a* values than those fed sorghum based DGS; however, no other differences were detected. In the second harvest group, the inclusion of all forms of DGS increased L*, and reduced a* and b* values which agrees with de Mello et al. (2012a). When looking at differences between the forms of DGS with the second harvest group, initially the authors noted the opposite effect of grain source the distiller grains originated from with corn DGS producing steaks with greater L* and reduced a* and b* compared to sorghum DGS. Steaks from steers fed DGS in the wet form had greater b* values than steaks from steers fed dry DGS (Gill et al., 2008). Roeber et al. (2005) agreed that increasing DGS inclusion increases discoloration rates and that b* values were increased in steaks from steers fed wet DGS compared to dry DGS but provided possible evidence that lower inclusions (10 to 25%; DM basis) could possibly have no damaging effects on color stability. Dietary inclusion of DGS at 10-25% DM are consistent with the ranges of DGS inclusion for meeting cattle's MP requirements.

In an attempt to increase profit potential of the ethanol fuel industry, many ethanol plants have begun to capture and sell a portion of the corn oil present in the solubles. The solubles portion of the oil is thought to not be bound to fiber particles, thus are removed via centrifugation of the solubles and destined for biodiesel production (Cantrell and Winsness, 2009). The oil removed through this process is different than the oil removed in wet milling industry where the corn germ is collected prior to the removal

of starch and wet corn gluten feed. The corn germ would be present in the dry milling industry that produces DGS, and the oil present in the germ would be bound making centrifugation of this oil fraction difficult. In an effort to determine the effects of the removal of oil via the centrifugation process, Domenech et al. (2014b) analyzed steaks from steers finished using de-oiled (7.9% fat) or normal fat (12.4%) DGS at 0, 35, 50 and 65% inclusion (DM basis), The authors reported that for steaks aged 21 days prior to fabrication that by day 6 of retail display, steaks from steers finished on the 65% normal fat DGS had the most discoloration followed by steaks from steers fed the 35% normal fat diet and the 65 and 50% de-oiled diet, while steaks from steers finished on the 35% de-oiled diet had the least discoloration (Domenech et al., 2014b). Thus it would be expected that the removal of oil from DGS would have only minimal impacts on meat quality since it is the bound and protected fat that is believed to cause most of the meat quality issues (Domenech et al., 2014a; 2014b).

Effects on Fatty Acid Prolife and Lipid Oxidation. When analyzing the fatty acid profile of dietary feedstuffs that enter the rumen of ruminant animals compared to what enters the duodenum of the small intestine, there is a significant reduction in the amount and degree of polyunsaturated fatty acids (PUFA). Feedstuffs may contain a large quantity of polyunsaturated fatty acids, but the rumen microbes remove much of the unsaturation points. According to Ducket et al. (2002), the high concentrate diets fed to finishing cattle contain primarily fatty acid 18:2, which accounts for nearly half of total PUFA found in beef and has received a great deal of attention as an explanation for increased lipid oxidation and meat color stability.

Dietary lipids enter the rumen were they are esterified and hydrolyzed by the bacterial lipases to produce fatty acids in a process called lipolysis. The fatty acids are then biohydrogenated in the rumen, removing points of unsaturation and generating monounsaturated and *trans*-fatty acids which can then be converted to saturated fatty acids by isomerization (Jenkins et al., 2008). The fatty acids are then packaged as triglycerol, phospholipids and cholesterol (Emery, 1979; Doreau and Ferlay, 1995). Once exiting the rumen, the packaged fatty acids enter the duodenum of the small intestine, the site of nutrient absorption. Absorption of fatty acids is dependent on the size of the micelle. Micelle size is enlarged with increased incorporation of PUFA, thus increasing the potential for absorption of more unsaturated fatty acids (Zinn et al., 2000). The packaged fatty acids are then transported to the liver through the blood system after combining with apolipoproteins where the complex can be disassembled to allow the fatty acids to be esterified. Lipoprotein structures are reformed and pass into the hepatic venous blood to allow circulation throughout the entire body. The fatty acids are incorporated into the various body tissues (muscle, mammary, and adipose) through the action of the enzyme lipoprotein lipase, where an increased concentration of fatty acids causes the fatty acid to transfer into the tissue (Emery 1979).

In a metabolism trial comparing DGS to corn oil, Vander Pol et al. (2009) reported that cattle fed DGS had greater amounts of long chain unsaturated fatty acids (18:1 *trans,* 18:1, and 18;2) and lower amounts of 18:0 reaching the duodenum, the site of fatty acid absorption, than those cattle that were supplemented corn oil. This allowed Vander Pol et al. (2009) to conclude that a portion of the fatty acids present in DGS is

protected in the rumen from biohydrogenation. Considering unsaturated fatty acids are more digestible than saturated fatty acids (Zinn et al., 2000; Lock et al, 2005), the feeding of DGS causes an increase in the amount of highly digestible, unsaturated fatty acids entering the small intestine. Once fatty acids reach the small intestine fatty acids are readily absorbed and can be incorporated into tissues. The deposition of these polyunsaturated fatty acids in muscle tissue is increased as DGS inclusion is increased linearly in finishing diets, causing an increase in the concentration of total polyunsaturated fatty acids, but concentrations of total saturated and monounsaturated fatty acids remain unaltered. Total polyunsaturated fatty acids account for only a small proportion of the fatty acids present in beef compared to the larger amounts of saturated and monounsaturated fatty acids. Thus there is less of a buffer effect in the proportion of polyunsaturated fatty acids than for the saturated and monounsaturated fatty acids. The increased polyunsaturated fatty acid concentration but constant saturated fatty acid concentration results in an increase in the polyunsaturated fatty acid to saturated fatty acid ratio (Gill et al., 2008; Depenbusch et al., 2009, Koger et al., 2010; Kinman et al., 2011; de Mello et al., 2012b). Segers et al. (2011) reported finishing diets containing DGS increased polyunsaturated fatty acids but also decreased monounsaturated fatty acid concentrations in beef compared to diets containing corn gluten feed and a corn only control, which would further negatively shift the ratio between polyunsaturated and saturated fatty acids.

The oxidation of the lipids, most notably the PUFA, present in beef is the primary causative agent for the development of rancidity and the degradation of beef color

resulting in reduced shelf life. The process of lipid oxidation has been shown to initiate the oxidation of the meat color pigment myoglobin into metmyoglobin (Hur et al., 2003). Feeding diets high in PUFA concentrations can accelerate this oxidation process. de Mello et al. (2012a) reported a linear increase in lipid oxidation with the linear increase of DGS in the finishing diet. Inclusion of 40% DGS in finishing diets caused an increase in lipid oxidation in ground beef as soon as day 2 of retail display compared to ground beef from steers fed dry rolled corn control diet (Koger et al., 2010).

In an effort to determine the effects of the removal of oil via the centrifugation process, Domenech et al. (2014a) analyzed steaks from steers finished using de-oiled (7.9% fat) or normal fat (12.4%) DGS at 0, 35, 50 and 65% inclusion (DM basis), The authors reported that the corn control diet had the least amount of PUFA, while the 35 and 50% de-oiled tended to contain greater amounts of PUFA than the corn control, but the 35, 50, and 65% normal fat diets and 65% de-oiled diets had an increased concentration of PUFA than the corn control diet (Domenech et al., 2014a).

Effects on Sensory Attributes. Aside from color acceptability, the next most important aspect of beef quality would be the overall eating experience. Multiple studies used Warner- Bratzler shear force values to indicate no tenderness differences between steaks from cattle fed corn control diets or fed various levels of DGS (Roeber et al., 2005; Gill et al., 2008; Kinman et al., 2011; de Mello et al., 2012a). Further taste panel and Warner – Bratzler shear force analyses performed by de Mello et al. (2012a) and Buttrey et al. (2013) supported the reports of Roeber et al. (2005), Gill et al. (2008) and Kinman et al.(2011) in terms of overall steak tenderness and also reported no differences in the amount

of perceived connective tissue. Contrary to those studies, Depenbusch et al. (2009) reported a linear increase in overall tenderness in a taste panel survey as DGS inclusion increased from 0 to 75% in the finishing diets. Sensory panelists in the study conducted by Depenbusch et al. (2009) also recorded measures of the amounts of perceived connective tissue present in the steak samples. The amount of connective tissue decreased linearly with increased concentrations of DGS which is a reflection of the increased tenderness scores (Depenbusch et al., 2009).

Tenderness is not the lone sensory measure of importance; beef flavor and steak juiciness are also significant characteristics. Studies utilizing taste panels indicate there are no differences in flavor, juiciness, and livery or off-flavor intensity for steaks from cattle fed various amounts of DGS compared to those fed corn control diets (Roeber et al., 2005; Gill et al., 2008; de Mello et al., 2012a). However, Depenbusch et al. (2009) found a quadratic relationship for beef flavor as DGS increased linearly in finishing diet with those fed no DGS having the least flavor and those fed 40 or 60% distillers having the most flavor. Calkins and Hodgen (2007) reported development of off-flavors in beef that had undergone retail display and experienced increased amounts of oxidation or development of rancidity. The influence of unsaturated fatty acids on the development of liver-like off-flavors in cooked beef was further established by Jenschke et al. (2007).

Effects of Distillers Grains Feeding Prior to Finishing. There has been recent interest in the use of DGS to grow cattle to increase profit potential in a backgrounding system (Gillespie 2013). Little is known about the lasting effects DGS supplementation prior to feedlot entry may have on the final beef quality after slaughter. Leupp et al. (2009)

evaluated short and long term feeding effects of 0 or 30% DGS in a 65% concentrate growing diet fed for 57 followed by a 102 day finishing period. Feeding 0 or 30% DGS in the growing, finishing or both phases, had no effect on 12-th rib fat thickness, marbling, or yield grades (Leupp et al., 2009). Similar results were found by researchers looking at the inclusion of DGS in only the finishing diet (Ham et al., 1994; Lodge et al., 1997; Vander Pol et al., 2009). Feeding DGS during the growing phase reduced b* values and tended to reduce L* but had no effect on a* values. Distillers grains inclusion in the finishing diet reduced a* values while having no effect on the other color space measurements (Leupp et al., 2009). Considering a* values are highly correlated with visual appearance scores (Zerby et al., 1999), the study conducted by Leupp et al. (2009) would appear to indicate that finishing diet impacts visual color stability more than diet composition during the growing phase.

The growing phase of the study by Leupp et al. (2009) lasted for only 57 days and the diet composition was more consistent with a typical feedlot starter ration than what would be offered during a backgrounding system. Buttrey et al. (2012) evaluated the impact supplementing DGS at 0.5% of body weight while grazing winter wheat pasture for an average of 128 days had on the final beef quality following subsequent finishing and slaughter. Distillers grains supplementation during backgrounding again showed no effects on any carcass traits. However, DGS supplementation altered the fatty acid profile of 17:0 and increased the amount of 18:2 compared to cattle supplemented with dry rolled corn (Buttrey et al., 2012). This altered fatty acid profile is consistent with the

reported altered fatty acid profile of steaks from cattle finished with DGS (Depenbusch et al., 2009; Koger et al., 2010; de Mello et al., 2012a).

RACTOPAMINE HYDROCHLORIDE

Mode of Action. Ractopamine hydrochloride (Elanco Animal Health; Greenfield, IN) is a beta-adrenergic agonist administered to beef cattle via feed supplementation during the last 28 – 42 days of the finishing period at a rate of 8.2 to 24.6 g/ton and 70 to 430 mg/ animal/ daily with no withdrawal period (FDA, NADA 141-221, 2003). Beta – adrenergic receptors are membrane bound receptors that belong to the large family of G-protein coupled receptors and are the binding site for the catecholamines epinephrine and norepinephrine (Beermann, 2002; Mills, 2002a). The beta – adrenergic receptors are classified into three different subtypes (β_1 AR, β_2 AR, and β_3 AR), which share a common transmembrane domain where the ligand (epinephrine, norepinephrine, or ractopamine hydrochloride) would bind the receptor (Mills, 2002a). The receptors are named in the order of highest affinity for norepinephrine. Ractopamine hydrochloride is an orally active phenethanolamine that is similar in structure to epinephrine and norepinephrine, thus has a high affinity to bind to the beta – adrenergic receptors (Beerman, 2002; Mills, 2002a). Winterholler et al. (2007) observed a tendency for ractopamine hydrochloride to increase the amount of β_2 – AR mRNA, but no differences were observed for β_1 – AR or β_3 – AR mRNA, indicating a possible binding selectivity. The binding of ractopamine hydrochloride to the receptor site elicits a response that causes an increase in the proportion of lean muscle mass relative to body fat (Beermann

2002; Mills 2002a). These compounds are fed during the final stages of finishing, just prior to harvest, where the animal is nearing maturity. As the animal reaches maturity, the rate of muscle deposition slows, but the rate of fat deposition increases. Supplementing cattle with ractopamine hydrochloride reduces the rate at which body fat is deposited, allowing for continued increase in the proportion of muscle growth through increasing muscle fiber hypertrophy (Beermann, 2002; Mills 2002a). However, as pointed out by Mills (2002b), with continued exposure to ractopamine hydrochloride, the beta – adrenergic receptors can become desensitized and the response to supplementation declines as the duration reaches the approved 42 d of supplementation.

Effects on Feedlot Performance Measures. Supplementing cattle with ractopamine hydrochloride during the final 28-42 days of the feedlot finishing period increases ADG, G:F, dressing percentage HCW, and FBW, while having little to no impact on DMI, 12^{th} rib fat thickness or marbling characteristics (Gruber et al. 2007; Quinn et al., 2008; Vogel et al., 2009; Boler et al., 2012; Bittner et al., 2014). Ractopamine hydrochloride is approved to be feed at 70 to 430 mg/ animal daily during the last 28 to 42 days of the feedlot finishing phase. Ractopamine hydrochloride supplemented at 200 or 300 mg/ steer daily dosage rates to steers during the last 28 days of feedlot finishing increased HCW 13.2 and 14.9 kg and live final body weight 14.8 and 14.6 kg compared to controls (respectively; Boler et al., 2012). Furthermore the authors noted that supplementing ractopamine hydrochloride increased G:F 45.4 and 47.5% and increased ADG 55.5 and 54.5% for 200 and 300 mg/ steer daily (respectively) over the controls. Dressing percentage was greater for steers supplemented ractopamine hydrochloride at 200 and

300 mg/ steer daily to 63.06 and 63.39%, respectively, compared to the control cattle dressing percentage of 62.27%. Supplementing ractopamine hydrochloride increase loin muscle area (83.91 and 84.04 for 200 and 300 mg/ steer daily; respectively) compared to the controls (80.04), though there was no difference between the 200 or 300 mg/ steer daily. The authors reported no differences in marbling scores, 12^{th} rib fat thickness, liver abscesses, calculated USDA yield grade, or quality grade distribution between the controls and supplementing ractopamine hydrochloride at either 200 or 300 mg/ steer daily (Boler et al., 2012). These data are supported by the summary of five studies reported by Vogel et al. (2009) utilizing 2,105 calf – fed and yearling Holsteins. Considering the calf – fed studies the authors reported increased ADG of 0.24 and 0.28 kg, increased HCW by 4.7 and 5.1 kg, increased LM area by 1.8 and 2.8 cm^2 compared to the controls for Holstein steers supplemented 200 and 300 mg/ steer daily ractopamine hydrochloride, respectively. In the studies supplementing ractopamine hydrochloride at either 200 or 300 mg/ steer daily increased G:F 14.4% compared to control steers receiving no supplementation (Vogel et al., 2009). Feedlot producers are constantly searching for methods to boost profitability, most commonly through efficiency. Increasing the amount of supplemented ractopamine hydrochloride from 300 to 400 mg/ steer daily and increasing the number of days ractopamine hydrochloride is supplemented could potentially provide an increase boost in efficiency. The effects of supplementing cattle 300 or 400 mg/ steer daily for the last 14, 28 or 42 days on steer growth performance and carcass characteristics were evaluated by Bittner et al. (2014). The authors reported supplementing ractopamine hydrochloride at 300 mg/ steer daily

increased HCW 4.84 and 7.33 kg, while supplemented at 400 mg/ steer daily increased HCW by 8.49 and 9.16 kg compared to controls for the last 28 and 42 days, respective (Bittner et al., 2014). Thus supplementing ractopamine hydrochloride at 400 mg/ steer daily is beneficial to increasing HCW compared to 300 mg/ steer daily, but no added benefit to increasing the number of days ractopamine hydrochloride is supplemented from 28 to 42.

The United States' beef industry is composed of numerous breed types, with geographical implications as to the selected breed type or breed composite, which potentially could have an impact as to the effects of supplementing ractopamine hydrochloride. Gruber et al. (2007) evaluated the effects of supplementing ractopamine hydrochloride at 200 mg/ steer daily for the final 28 days of the finishing period to steers sorted by breed type (British, Continental crossbred, and Brahman crossbred). The authors reported that there was no interaction between ractopamine hydrochloride supplementation and breed type; however supplementation of ractopamine hydrochloride affected feedlot performance and carcass characteristics. Steers supplemented with ractopamine hydrochloride had increased ADG, but similar DMI thus resulting in an improved G:F compared to steers that did not receive ractopamine hydrochloride. However, supplementation of ractopamine hydrochloride to steers had no effect on dressing percentage, adjusted fat thickness, or percentage KPH. Steers that received ractopamine hydrochloride supplementation produced a 6 kg heavier carcass than the control steers (365 and 359 kg.; respectively) and ractopamine hydrochloride

supplemented steers had an increased LM area compared to control steers (81.7 and 84.0 cm; respectively; Gruber et al. 2007).

As feedlots become increasingly aggressive in the implant strategies utilized along with the use of ractopamine hydrochloride, there is a possibility for a potential interaction between these two growth promotants. Sissom et al. (2007) evaluated this potential using 1,147 heifers implanted on arrival with either Revalor-200 (200 mg trenbolone acetate and 20 mg estradiol) or Revalor – IH (80 mg trenbolone acetate and 8 mg estradiol) which were reimplanted with Finaplix – H (200 mg trenbolone acetate) on d 58 while being supplemented either 0 or 200 mg/ heifer daily of ractopamine hydrochloride. Revalor – 200 is the more aggressive strategy with a strong combination of the growth hormones trenbolone acetate and estrogen, which would lead to a greater shift in the heifer's growth curve. The less aggressive strategy of using a weak combination initially (Revalor – IH) followed by a strong androgenic implant (Finnaplix – H) would not shift the growth curve as much as using Revalor – 200. However, no interaction between implant strategy and ractopamine hydrochloride supplementation were observed for any of the feedlot finishing performance measures (ADG, DMI, G:F, HCW, LM area, 12^{th} rib fat, marbling score, or calculated yield grade). Ractopamine hydrochloride supplementation did, however, compared to controls increase ADG (1.39 vs. 1.42 kg/ d), G:F (1.80 vs. 1.87), HCW (344.5 vs. 349.5), LM area (93.8 vs. 96.3) and decreased 12^{th} rib fat (1.24 vs. 1.16) and calculated yield grade (2.61 vs. 2.44) for cattle supplemented 0 or 200 mg/ heifer daily; respectively. The authors reported a tendency for an increase in β_2 – AR mRNA levels to increase when cattle where supplemented

ractopamine hydrochloride which is consistent with observations made by Winterholler et al. (2007). The mode of action that these two growth promotants use is unique to each one. Implants utilize hormonal control, estrogen and testosterone, to increase production of muscle IGF-I which stimulates muscle growth (Johnson et al., 1998; Dunn et al., 2003). Ractopamine is a beta-adrenergic agonist that binds to beta – adrenergic receptors on the cell membrane that reduces the rate of fat deposition, while increasing muscle fiber hypertrophy (Beermann 2002; Mills 2002a).

Effects on Meat Quality. Supplementing cattle with ractopamine hydrochloride during the last 28-42 days of the finishing period has clear economic benefits to the feedlot producer, but it remains important that the quality of the beef produced through the use of the technology remains of similar quality standards as beef produced without ractopamine hydrochloride. An increase in the longissmus muscle area could potentially reduce beef tenderness or marbling. However, there is little to no effect on the quality of the beef produced from supplementing ractopamine hydrochloride (Gruber et al., 2007; Quinn et al., 2008; Vogel et al., 2009; Boler et al., 2012; Garmyn et al., 2014; Howard et al., 2014). Several studies have shown statistical increases in WBSF values for steaks from cattle supplemented with ractopamine hydrochloride when aged relatively short time (4-7 d), but the magnitude of the increased WBSF are small and not likely to be meaningful to the consumer. However, following a more common industry aging period (14+ d), the observed differences in WBSF values are reduced (Gruber et al., 2007; Boler et al., 2008). Gruber et al. (2007) evaluated the effects of ractopamine hydrochloride supplementation at 200 mg/ steer daily for 28 days and steer breed type, there was a

tendency for supplementation to reduce mean marbling score compared to control steers (477 and 487; Slight = 400, Small = 500; respectively). Furthermore, Gruber et al. (2008) conducted both Warner-Bratzler shear force (WBSF) and slice shear force (SSF) along with a trained sensory panel to evaluate the effects of ractopamine hydrochloride supplementation and breed type on palatability of steaks aged 3, 7, 14, and 21 postmortem. Steaks from steers supplemented with ractopamine hydrochloride had greater average WBSF (4.60 and 4.22 kg) and SSF values (19.64 and 18.24 kg) than steaks from control steers. According to the trained sensory panel results, steaks from steers supplemented ractopamine hydrochloride compared to control steaks were less tender (8.95 and 8.09; 0 = not tender and 15 = very tender) and had less juiciness (8.07 and 7.41; 0 = not juicy and 15 = very juicy) with a tendency for a reduction in perceived beef flavor (6.93 and 6.67; 0 = none and 15 = intense), but no differences in presence of an off – flavor (0.48 and 0.45; 0 = none and 15 = intense). In the summary of five studies utilizing Holstein steers conducted by Vogel et al. (2009), the authors reported a reduction in 12^{th} rib fat thickness for steers supplemented 300 mg/ steer daily, but no observed differences between 200 mg/ steer daily and the controls. Considering most cattle are marketed when they reach a common body composition endpoint, the difference observed would be due more to marketing of cattle, and cattle requiring more days on feed to achieve the same targeted fat endpoint. However when analyzing marbling scores, the authors noted inconsistent reduction in marbling scores (514.8, 497.7 and 507.0 for 0, 200, and 300 mg/ steer daily ractopamine hydrochloride) for steers

supplemented 200 mg/ steer daily, but no differences between 300 mg/ steer daily or the controls.

In a study evaluating the effects of beta- agonist supplementation on consumer acceptability of beef steaks, Garmyn et al. (2014) compared ractopamine hydrochloride, zilpaterol hydrochloride, and no beta – agonist supplementation in a large 1,914 head study. The authors observed a beta – agonist by aging interaction for WBSF with steaks aged 14 days from zilpaterol hydrochloride supplemented cattle requiring the greatest shear force, while ractopamine hydrochloride and the control cattle had the lowest required shear force (4.38, 3.69, 3.64 kg for zilpaterol hydrochloride, ractopamine hydrochloride and control; respectively) When analyzing steaks aged 21 days however, ractopamine hydrochloride supplementation provided steaks with the lowest WBSF, with the control now being intermediate and zilpaterol hydrochloride steaks having the greatest shear force (3.79, 3.28, and 3.50 kg for zilpaterol hydrochloride, ractopamine hydrochloride and control; respectively). However, when analyzing the SSF values, no differences were observed between steaks from the control or ractopamine supplemented cattle, but zilpaterol hydrochloride supplementation increased SSF values in both 14 and 21 day aging periods. Steaks aged 14 days from cattle supplemented zilpaterol hydrochloride also received lower consumer acceptability ratings for tenderness, flavor, and overall liking compared to steaks from ractopamine hydrochloride supplemented and control cattle, but no differences due to beta – agonist supplementation for juiciness, flavor and overall acceptability. The only differences in the consumer taste panel then for steaks aged 21 days due to beta – agonist supplementation were for tenderness and

perceived juiciness, with steaks from cattle supplemented zilpaterol hydrochloride receiving lower acceptability than steaks from cattle supplemented ractopamine hydrochloride or control cattle. The authors concluded that increasing aging period from 14 to 21 days would reduce the differences observed in shear force and tenderness scores due to feeding the beta – agonist zilpaterol hydrochloride to achieve scores comparable in acceptability to ractopamine hydrochloride supplemented or control cattle (Garmyn et al., 2014). Minimal effects of ractopamine hydrochloride supplementation on beef quality agrees with previous research (Gruber et al., 2007; Quinn et al., 2008; Vogel et al., 2009)

OMNIGEN – AF

OmniGen – AF is a commercial feed additive that provides a supplemental source of B- complex vitamins and live yeast cells marketed to provide an immune system boost to the animal (Prince Agri Products, Inc., 2006.). Georges et al. (2005) reported that supplementation of OmniGen – AF at 1% of the diet DM increased BW gain (1.9 to 2.8 g), and G:F by day 14, while also observing a six fold increase in neutrophil L – selectin, a measure of immune function in rats not immunosuppressed by dexamethasone injections. However, in rats that were immunosuppressed by injections of dexamethasone, supplementing OmniGen – AF was not able to overcome the effects on the immune system. Supplementation of OmniGen – AF increased L – selectin concentrations in lambs that were immunosuppressed via daily injections of dexamethasone, but no effects on neutrophil interleukin -1β (IL-1β) concentrations. Furthermore, in lambs that experienced a pathogen challenge (*Aspergillus fumigatus*; > 1

million spores/ g), OmniGen – AF supplementation increased concentrations of both L – selectin and IL-1β (Wang et al., 2004).

Far more research on the effects of supplementing OmniGen - AF has been performed in the dairy industry. Chapman et al. (2005) evaluated the effects of supplementing OmniGen – AF at 56 g/ cow daily in Holstein cows on milk production and persistence of milk yield during a 60 day field trial. Daily milk production was increased from 33.4 to 34.1 kg/ cow daily by including Omnigen – AF to the cow's final diets while also increasing the persistence of milk yield. Milk production dropped 2.42 kg/ cow daily for cow's not being supplemented OmniGen – AF, but cow's receiving the supplement only declined 1.08 kg/ cow daily in milk yield throughout the trial. The increased milk yield persistence was more substantial in cows in their third lactation with those not receiving OmniGen supplementation declining at 3.06 kg/ cow in daily milk production, but cow's receiving the supplement increased 0.05 kg/ cow daily during the 60 day trial (Chapman et al., 2005). Wang et al. (2009) attempted to determine the mechanism to which OmniGen – AF boosts immune function in dairy cattle. The authors used 8 periparturient Jersey cows that were fed either a control dry cow diet or the same diet supplemented with 56 g/ cow daily of Omnigen – AF for the month prior to expected calving date with blood samples collected fifteen hours post calving for evaluation of neutrophil gene expression following the surge of cortisol associated with calving. The addition of OmniGen – AF to the diet increased total white blood cell numbers (6950 and 10300 for control and OmniGen – AF; respectively) which was caused by a significant increase in total lymphocytes (4000 and 5960 for control and OmniGen – AF;

respectively) and a tendency for an increase in neutrophils (2456 and 4200 for control and OmniGen – AF; respectively). Furthermore, the authors performed a microarray analysis to determine the genes that were either up or down regulated through the addition of OmniGen – AF and reported that 12 genes were up-regulated and 6 genes were down-regulated. Particular interest was given to interleukin-4 receptor-α (IL – 4Rα) and interleukin converting enzyme (ICE): caspase I. Supplementation of OmniGen – AF increased the concentration of IL – 4Rα 5.2 - fold when added to the diet and functions as an anti – inflammatory and increases neutrophil IL – 1β production. The addition of OmniGen – AF also increased the concentration of ICE 2.9 times the concentration observed in the control cows and functions as the rate – limiting enzyme converting pro – IL -1β to IL-1β. Thus the increased production of both of the mentioned neutrophils result in increased production of IL - 1β which functions to activate adaptive immunity (Wang et al., 2009).

Very little research has been conducted using OmniGen – AF in the beef industry. In a 44 day feedlot receiving study performed by Reuter et al. (2007), 199 head of newly received crossbred heifers were fed a 60% concentrate diet based on steam flaked corn and alfalfa hay with or without supplemented OmniGen – AF and Sucram C – 150 (0.68 and 26.7% supplement DM, respectively, replacing ground corn) with the supplement included at 3.0% (DM basis) of the diets. The inclusion of Sucram and OmniGen – AF in the receiving diets had no effect on heifer growth performance (FBW, ADG, DMI, and G:F) during the 44 day receiving period. Finally, receiving period diet had no effects on 240 day feedlot growth performance (HCW, FBW, and ADG), along with no effects

on12th rib fat thickness, LM area, USDA Yield Grade, and KPH %. However, the inclusion of Sucram / OmniGen – AF combination decreased marbling score (389.4 and 370.7 with 300 = slight, for control and Sucram / OmniGen – AF; respectively) with a trend for the combination to decrease the percentage of heifers that graded USDA Choice (38.5 and 26.1%, for control and Sucram / OmniGen – AF; respectively). The authors were unaware of any mechanism that would cause the Sucram / Omnigen – AF combination to reduce marbling scores, but noted that reduced in marbling scores were reported by McMeniman et al. (2006) when Sucram was supplemented during the feedlot receiving period. Reuter et al. (2007) also drew blood samples on d 0, 16, 30, and 30, and 44 during the receiving period to be analyzed for signs of a boost in immune system response to stress associated with newly received feedlot cattle. However, the only measure of immune function that was affected by receiving period diet was the concentration of haptoglobin was elevated on d 16 for the control cattle (0.13, 0.69, 0.06, and 0.13 for d 0, 16, 30, and 44; respectively), but no differences were observed across receiving days for heifers supplemented the feed additive combination (0.15, 0.21, 0.18, and 0.11 for d 0, 16, 30, and 44; respectively; Reuter, 2007). Newly received feedlot cattle would typically express increased signs of immune system challenge 7 – 21 d post receiving as the stressors cattle are exposed to begin to overpower the immune system and the passive immunity received from the cow declines (Edwards, 1996). Thus the increase in haptoglobin concentration observed on day 16 in the control cattle would be expected. Receiving period diet had no effect on concentrations of IL – 4, IL – 6, TNFα, INFγ, SAA, IBR titer, or L – selectin. Furthermore, there was no effect of the additive

combination on receiving period morbidity (8 and 10 % for control and Sucram / OmniGen – AF; respectively). However, the authors noted the 9.5% morbidity and 0.5% mortality (0 and 1% for control and Sucram / OmniGen – AF; respectively) during the receiving period was less than anticipated which may indicate heifers' immune system may not have been compromised enough to elicit a response to OmniGen – AF supplementation (Reuters, 2007).

CONCLUSION

Distillers grains are a valuable feedstuff to be used in both the feedlot sector and the yearling beef production system due to the greater energy content relative to corn, the highly digestible fiber that DGS are composed of, and the high percentage of crude protein DGS contains. The inclusion of DGS in feedlot finishing diets up to 15% (DM basis) provide a cheaper source of protein than traditional feedlot protein sources. Furthermore, the greater energy content of DGS (110-150%) relative to corn allows for increased ADG and an improved G:F, that when combined with relatively low price (~85-110% of corn; DM basis) provides substantial economic benefits to the feedlot industry to increase level of inclusions in feedlot diets that exceed cattle protein requirements. The combination of the increased energy content and reduced cost of protein supplementation further enhances the economic benefits of utilizing DGS. In forage based yearling beef production systems, DGS can be used as either an economic

source of supplemental protein or as a source of energy. Distillers grains are excellent supplements in forage systems since distiller grains do not contain the starch that inhibits fiber digestion like grain sources would. As mentioned previously, DGS contain a large amount of protein that consists of a large amount of rumen undegradeable protein that when supplemented at low to moderate levels meet the calves' metabolizable protein requirement. Higher levels of supplementation can serve as source of supplemental energy that can replace and extend the forage source being used to grow calves, while improving profitability of the production system.

However, there is a cost that comes to the beef industry as a whole due to the inclusion of DGS in finishing rations after the cattle have been harvested and the beef products reaches retailers. Fresh beef from cattle fed DGS experience increased rates of lipid and color pigment oxidation that leads to discoloration and a reduction of consumer acceptability. Furthermore, the increased amount of oxidation can potentially lead to the development of liver- like or off-flavors that affect consumer acceptability. A possible cause of the mentioned effects from feeding DGS to finishing cattle on beef quality is that the concentration of fatty acid 18:2 and total poly-unsaturated fatty acids is increased in the beef produced from cattle fed DGS. There is also evidence that the use of DGS in yearling beef production systems has implications on the fatty acid profile of beef, even a year prior to eventual harvest of the cattle. The effect on the fatty acid profile then raises the question of whether supplementing DGS in a yearling production system affects discoloration, oxidation, or sensory traits of beef.

While DGS increase profit potential by replacing corn in feedlot finishing diets, feedlots are increasing the use of technology including beta- agonists, such as ractopamine hydrochloride, during the final days 28 – 42 days of finishing to continue to improve profitability of cattle feeding. The supplementation of ractopamine hydrochloride increases ADG, G:F, FBW and HCW, thus increases profit potential from increased efficiency of feed resources while allowing the producer to sell more weight. However, there are claims that the use of beta – agonists increases immune system stress and potentially deathloss. OmniGen – AF is a commercial feed additive containing live yeast and B – vitamins that has been shown in research trials with rats, lambs, and dairy cows to increase immune system function. However, little research has been done conducted looking at the effects of supplementing OmniGen – AF in beef cattle, especially during the late stages of production when ractopamine hydrochloride would be fed.

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CHAPTER III: EFFECTS OF FEEDING DISTILLERS GRAINS THROUGHOUT A YEARLING BEEF PRODUCTION SYSTEM ON MEAT QUALITY ATTRIBUTES[1]

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ABSTRACT: Distillers grains (DGS) fed in a yearling beef production system were evaluated to determine the effects of longterm exposure to DGS on meat quality characteristics. Crossbred heifers (n = 229; initial BW = 225 kg ± 2) were used in a randomized block design by applying a 2 x 2 x 2 factorial arrangement of treatments. Factors included winter supplementation while grazing corn stalks with modified DGS (MDGS) at either 0.91 kg (LW) or 2.3 kg (HW) on a DM basis; summer grazing supplementation with dry DGS at 0.6% BW (SS) on a DM basis daily or no supplementation (NS); and finishing diet containing either 40% wet corn gluten feed (CGF) or 40% MDGS (DGF) on a DM basis. Heifers were blocked by BW and assigned randomly within block to treatment prior to start of each production phase within previously applied treatments. Choice grade strip loins (n = 12) were collected from each of the 8 treatments. After 7 d postmortem aging, strip loins were fabricated into 2.5 cm thick steaks. The remaining strip loin was aged an additional 14 d before fabrication was repeated. Discoloration percentage was estimated daily during 7 d retail display by a 5-member panel. The HW supplementation increased discoloration 15% compared to LW supplementation ($P < 0.01$). An interaction ($P = 0.01$) between summer supplementation and finishing diet was observed. Within CGF, SS increased discoloration by 30% ($P = 0.01$) compared to NS, whereas were no differences between SS or NS in steaks from DGF cattle ($P = 0.95$). Finishing diet had no effect ($P > 0.10$) on discoloration scores for retail d 1 - 5 and d 1 - 3 for steaks aged 7 and 21 d, respectively; however, scores increased for the DGF ($P < 0.01$) compared to CGF on d 6 - 7 and d 4 - 6 for steaks aged 7 and 21 d, respectively. Winter supplementation interacted with finishing diet for

concentrations of fatty acid 18:2 and total polyunsaturated fatty acid concentrations measured as a percentage of wet muscle tissue ($P = 0.02$ and 0.01; respectively). Within CGF, HW increased concentrations of 18:2 and total polyunsaturated fatty acids 21% and 19% ($P < 0.01$ and < 0.01, respectively), but there were no observed differences in DGF steaks ($P = 0.43$ and 0.33, respectively). Supplementing with DGS prior to finishing was not additive in impacting the color stability and overall shelf-life of retail beef when cattle were finished using DGS; however, DGS fed during the backgrounding phase can affect beef quality when DGS are not included in the finishing diet.

Key words: Beef, Distillers grains, Shelf life

INTRODUCTION

Distillers grains plus solubles (DGS) are commonly fed as an economic energy source replacing corn in beef cattle diets, which increases ADG, improves G:F, and reduces the costs of production (Larson et al, 1993; Ham et al., 1994; Klopfenstein et al. 2008). A portion of the corn oil present in DGS may be protected from rumen biohydrogenation resulting in an increased fat digestibility and concentration of polyunsaturated fatty acids (PUFA) reaching the duodenum (Vander Pol et al., 2009). The increased concentration of PUFA reaching the duodenum causes an increase in the amount of PUFA that is absorbed. As the concentration of DGS inclusion in finishing diets increases, there is a linear increase in PUFA concentration within the beef (Koger et al., 2010; de Mello et al., 2012). The increased PUFA results in higher oxidation potential and decreased color stability of the retail beef shortly after being placed in the retail case (Koger et al., 2010; de Mello et al., 2012). Decreased color stability is caused by the

PUFA being more readily oxidized than the monounsaturated or saturated fatty acids. The increased oxidation results in a decreased retail shelf-life and a potential loss of retail value. Sherbeck et al. (1995) estimated that 2 to 20% of fresh beef is discounted or discarded due to loss of desirable color in U. S. retail stores.

Supplementing DGS to cattle backgrounded on cornstalks or grazing pasture throughout a yearling beef production system is economically beneficial (Gillespie, 2013). However, supplementing DGS would increase the total amount of dietary PUFA to which the animal is exposed to throughout the production system if DGS were also included in the finishing diet. There is currently limited research evaluating this effect on the quality of retail beef. Buttrey et al. (2012) evaluated the effects of supplementing dried DGS to stocker cattle grazing winter wheat pasture prior to feedlot entry and reported that DGS supplementation on wheat pasture increased the PUFA concentrations in beef, but no further meat quality analyses were performed.

The objective of this study was to determine if the supplementation of DGS during winter backgrounding and summer grazing is additive to the effects of feeding DGS in finishing diets on the fatty acid profile, color stability, lipid oxidation, and overall shelf-life of beef steaks.

MATERIALS AND METHODS

All procedures and facilities related to live animals for this study were approved by the Institutional Animal Care and Use Committee of the University of Nebraska.

Animal Production System

Crossbred spayed heifers (n = 229; initial BW = 225 kg ± 2) were used in a randomized block design with a 2x2x2 factorial arrangement of treatments. Heifers were blocked by one of two marketing dates. Treatment factors were: winter supplementation of 0.91 or 2.30 kg (DM basis) of modified DGS while grazing corn stalk residue, summer supplementation of 0.60% of heifer BW of dried DGS (DM basis) or no supplementation while grazing summer range, and finishing diet composition of either 40% modified DGS or 40% wet corn gluten feed (Figure 1). Heifers were received in October 2011 at the University of Nebraska Agricultural Research and Development Center (ARDC) feedlot near Mead, Nebraska. At receiving heifers were weighed and vaccinated according to UNL health protocols, individually tagged with a numbered panel tag, electronic identification tag, and a metal clip tag. Heifers were vaccinated on arrival for prevention of *infectious rhinotracheitis virus, bovine virus diarrhea, parainfluenza and bovine respiratory syncytial virus* (BoviShield Gold 5, Zoetis, Inc., Kalamazoo, MI), for control of *Haemophilus somnus*(Somubac, Zoetis, Inc.), and for control of *pasteurella* (One Shot, Zoetis, Inc.). Along with vaccinations, heifers also received injection of a parasiticide (Dectomax; Zoetis, Inc.). Heifers were revaccinated two weeks later using BoviShield Gold 5 (Zoetis, Inc.) and vaccinated for protection from *Clostridium chauvoei* (Blackleg), *septicum* (Malignant edema), *novyi* (Black disease), *sordellii, perfringens* Types C&D (Enterotoxemia), and *Haemophilus somnus* (Vision 7/ Somnus, Merck Animal Health, Summit, NJ), and administered a vaccination at revaccination for pinkeye protection against *Moraxella Bovis* (Piliguard, Merck Animal Health). Heifers were poured in

February with a parasiticide (Phonectin, Teva Animal Health, St. Joseph, MO). Prior to revaccination, heifers were limit fed a diet of 50% alfalfa hay, 50% wet corn gluten feed (Sweet Bran; Cargill, Blair, NE) at 1.8% of BW daily for 5 days to minimize differences in gut fill to allow determination of an initial BW with BW being recorded and averaged over two consecutive days (Stock et al., 1983; Watson et al., 2013). Heifers were stratified by average initial BW and assigned randomly and sorted into one of two winter backgrounding supplementation levels: 0.91 – kg DM modified DGS with solubles (MDGS; LW); or 2.3 –kg DM MDGS (HW) with 115 heifers assigned to High treatment and 114 assigned to Low treatment. Winter supplement was provided as heifers grazed cornstalks at the ARDC from late fall until early spring (Nov. 22, 2011 to April 17, 2012).

At the conclusion of the winter backgrounding phase, heifers were dry – lotted in pens for 24 hr and then surgically spayed by a DVM using the Kimberling – Rupp procedure (Rupp and Kimberling, 1982). Heifers then grazed bromegrass pastures at the ARDC for 31 days at which point heifers were then placed in feedlot pens for five d. Heifers were limit fed a diet of 50% alfalfa hay, 50% wet corn gluten feed (Sweet Bran; Cargill, Blair, NE) at 1.8% of BW daily for five d and BW collected on two consecutive days with the average BW used to assign heifers to one of two summer treatment groups while maintaining previously applied winter backgrounding treatments. Heifers were implanted with Revalor – G (40 mg trenbolone acetate and 8 mg estradiol; Merck Animal Health), poured with a parasiticide (Phonection, Teva Animal Health), given a vaccination for pinkeye protection (Piliguard, Merck Animal Health), and administered a

Python MAGNUM insecticide ear tag (Y-Tex Corporation, Cody, WY). Treatments during the summer were dry DGS diet supplemented at 0.6% BW daily (SS) or no supplementation (NS; n = 57, 58, 58, 56 for HW- NS, HW-SS, LW-NS, LW-SS, respectively) as heifers grazed native Sandhills range for 111 days at the UNL Barta Brother's Ranch near Rose, NE.

Heifers were then transported back to the ARDC near Mead, NE limit fed a diet of 50% alfalfa hay, 50% wet corn gluten feed (Sweet Bran; Cargill, Blair, NE) at 1.8% of BW daily 8 d and weighed two consecutive days during which heifers were implanted with Revalor – 200 (200 mg trenbolone acetate, 20 mg estradiol; Merck Animal Health).. Heifers were then stratified by feedlot entry BW within previous winter and summer treatment groups into an early or late slaughter group for each of the two finishing period treatments. Dietary treatments consisted of 40% wet corn gluten feed (Sweet Bran; CGF) or 40% MDGS (DGF) with the remainder of the diet consisting of 50% high moisture corn, 5% wheat straw, and 5% supplement. Diets were formulated to contain 30 g/ ton of monensin (Rumensin, Elanco Animal Health) and 90 mg/ heifer tylosin (Tylan, Elanco Animal Health). Wet corn gluten feed was used as a low fat fiber source following removal of the germ fraction of the corn kernel during the wet milling process as a control for comparison to DGS during the finishing period. Heifers were marketed in two time points, with one pen per treatment represented at each marketing date, resulting in 113 DOF for cattle slaughtered in the early group and 134 DOF for cattle slaughtered in the late group.

Carcass Sampling and Fabrication

Heifers were harvested at a commercial abattoir (Greater Omaha Packing Co., Omaha, NE) on January 9 and January 30, 2013. At 48 h postmortem, USDA quality grades (marbling score, texture, and distribution) were assigned to carcasses by a USDA grading supervisor. Six carcasses were selected during both harvest periods from each of the 8 treatments. To qualify for selection, carcasses were required to be of A-maturity and USDA Choice quality grade. After selection, strip loins (IMPS #180, NAMP 2007) from the left side of each carcass were labeled with numbered push-pins and carcass ink to preserve identity during the fabrication process. Selected strip loins samples were collected, labeled with additional laminated numbered tags, vacuum-packaged, boxed and shipped back to the Loeffel Meat Laboratory at the University of Nebraska-Lincoln. Strip loins were placed in a carcass cooler maintained at 2°C for the 7 and 21 d wet aging periods prior to steak fabrication.

Strip Loin Fabrication

After the 7 d postmortem aging period strip loins were fabricated beginning on the cranial end into four (steaks 1-4) 2.5 cm thick steaks and one (steak 5) 1.3 cm thick steak. Steaks 1 and 2 were designated for objective tenderness test on d 0 and 7 of retail display, respectively. Steak 3 was designated as retail d 0 for laboratory analysis of fatty acid profile, lipid oxidation, and proximate analysis. Steak 4 was retained as a backup. Steak 5 was cut in half from the cranial to the posterior aspect of the *longissmus* muscle to generate two 1.3 cm thick steaks for lipid oxidation analysis at retail d 4 and 7 respectively. All steaks were trimmed to 0.6 cm subcutaneous fat, except for steak 3

which was trimmed entirely of subcutaneous fat. The remaining strip loin was vacuum sealed in its original package and aged an additional 14 d providing for a total postmortem aging of 21 d before the steak fabrication process explained above was again performed.

Steaks 1, 3, and 4 were individually vacuum-packaged in a nylon-polyethylene vacuum pouches (3 mil STD barrier, Prime; St. Louis, MO) using a Multivac Packaging machine (MULTIVAC C500, Multivac Inc. Kansas City, MO) and stored at -20°C until laboratory analysis. The remaining steaks (2 and 5) underwent simulated retail display, maintained at 2°C, were matched by treatment and paired on polystyrene foam trays covered with oxygen - permeable film. Trays were placed in the coolers randomly and rotated daily to reduce variation in light intensity or temperature. Following the retail display simulation, steaks were then vacuum packaged and frozen in the same manner explained previously for steaks 1, 3 and 4.Subjective discoloration scores were performed by 5 trained panel members each d with the score based upon the visual percent discoloration (0% = no discoloration; 100% = completely discolored) of each steak.

Warner-Bratzler Shear Force

Steaks for subjective tenderness (steaks 1 and 2) were removed from the freezer and thawed for 24 hr at 3°C. Internal steak temperatures were monitored and collected while cooking using an OMEGA thermometer (Model 450A, OMEGA Engineering Inc., Stamford, CT) with a type T thermocouple (Model L-0044T Fine Wire Thermocouple, OMEGA Engineering Inc., Stamford, CT) that was placed in the geometric center of the steak. Steaks were grilled on a Hamiltion Beach Indoor-Outdoor Grill (Hamiltion Beach/

Proctor Silex, Inc., Catalog No. HB9, Model 31605A, Series type G16 Grill, 120 v~60 Hz, 1200 W) to an internal temperature of 35°C on one side, flipped and were then cooked on the other side to an internal temperature of 71°C. Steaks were then removed from the grill and placed on plastic trays and covered with oxygen permeable film and chilled overnight at 3°C. The next morning steaks were removed from the cooler and six 1.3 cm diameter cores were removed parallel to the muscle fiber using a Delta 20.3 cm Drill Press (Mfg. Ser. No. W9609, Model 11-950, Delta International Machinery Corp., Pittsburgh, PA). These six cores were then individually sheared utilizing an Instron Universal Testing Machine (model 55R1123, Instron Corp., Canton, MA) with a Warner-Bratzler blade with 250 nm/min crosshead speed and a 500-kg load cell. The average of the six cores represented the shear force for each steak.

Laboratory Analyses

In preparation for laboratory analyses steak 3 (retail day 0) and the two halves from steak 5 (retail days 4 and 7) each were cut into 0.5 cm^3 cubes, flash frozen in liquid nitrogen and pulverized in a blender (Waring Commercial, model 51BL32, Torring, CT). The powdered samples were transferred to small plastic bags and stored at -80°C.

Lipid oxidation was measured using a thiobarbituric acid assay (TBA; Buege and Aust, 1978; as modified by Ahn et al., 1998) at 0, 4, and 7 days of retail display to assess the rate of oxidation across days of retail display. The TBA assay was done using 5.0 g of powdered steak sample in duplicate 50 mL conical tubes that had 14 mL of ddH_2O and 1.0 mL of butylated hydroxyanisole added before being homogenized for 15 sec with a

polytron and placed in centrifuged. One mL of homogenate was then transferred to a 15 mL conical tube to which 2 mL of thiobarbutaric acid/ trichloracetic acid solution. Samples were then vortexed and incubated for 30 min in 70°C water bath to develop color. Samples again were centrifuged before duplicate aliquots of 200 µL from each tube were transferred onto a 96 well plate. Light absorbance for each well was read at 540nm.

The fatty acid profile of steak 3 was prepared by extracting lipid using a choloroform-methanol procedure (Folch et al., 1957). Fatty acid methyl esters were prepared (Morrison and Smith, 1964; Metcalfe et al.,1996) from extracted lipids and analyzed using gas chromatography (Hewlett-Packard Gas Chromatograph; model 6890 series, Agilent Technoligies, Santa Clara, CA) . A capillary column [Chrompack CP-Sil 88 (0.25 mm x 100 m)] was used and oven temperature was programmed from 140°C to 220°C at 2°C/ min and held at 220°C for 20 min. Injector and detector temperatures were maintained at 270°C and 300°C respectively. Helium was used as the carrier gas with a flow rate of 30 mL/min. Fatty acids were identified through comparison of retention times with known standards.

Fat content was determined by weighing out 2.0 grams of powdered sample from steak 3 into filter paper (Whatman #2) envelope and ether extraction by the Soxhlet procedure (AOAC 960.39, 1990). Moisture was determined by drying in a forced air oven overnight, with samples placed in a dessicator and allowed to equilibrate with room temperature before recording the final weights.

Statistical Analysis

Data were analyzed using the GLIMMIX procedure in SAS v. 9.2 (SAS Institute, Inc., Cary, N. C.) to test the effects of winter, summer and finishing dietary treatments as well as aging period, and retail display and the associated interactions. Individual strip loin served as the experimental unit. Discoloration data were analyzed as repeated measures where day served as the repeated variable. Various covariance structure models were tested and type AR(1) was selected for final analysis based on the best fit model. Effects were considered significant when $P \leq 0.10$, with tendencies declared when P – values were between 0.10 and 0.15.

RESULTS AND DISCUSSION

Animal performance and diet nutrient profiles previously have been reported (Gillespie, 2013). Due to sampling conditions and logistics at the plant only 43 of the targeted 48 strip loins were collected on the first slaughter date. Additional samples were then collected during the second slaughter date to account for those treatment groups represented by the missing strip loins. Fifty - one of the then targeted 53 loins were collected on the second slaughter date for a total of 95 loins collected for meat quality analysis. The targeted total of 12 loins were collected for all treatments except for 13 strip loins collected for the HW-NS-CGF treatment and 11 strip loins collected for the HW-SS-DGF and LW-SS-DGF treatments.

Color Scores

There were no interactions for color scores between winter supplementation and finishing diet for discoloration ($P = 0.39$), winter and summer interaction ($P = 0.61$) or a

three way interaction between winter supplementation, summer supplementation or finishing diet ($P = 0.85$). Visual color evaluations (Figure 2) exhibited the expected increased rate of discoloration that is associated with aging steaks 21 d versus 7 d ($P < 0.01$) and with retail display d ($P < 0.01$). Within aging period, there were no effects ($P > 0.10$) of finishing diet for the retail days 1-5 for those steaks aged 7 days and days 1-3 for those aged 21 days. However, there was an increased rate of discoloration for those fed the DGF ($P < 0.01$) during the finishing phase on d 4, 5, and 6 for the 21-d aged steaks and days 6 and 7 for the 7-d aged steaks compared to those finished on the CGF diet. Overall, those steaks from heifers finished on the DGF diet had greater ($P < 0.09$) discoloration averages than those finished on the CGF diet, which is expected considering the differences observed across retail display between CGF and DGF diets. The effect of the finishing diet carries over into the interaction ($P = 0.014$) between summer supplementation and the finishing diet (Table 1) where there was a difference in the average retail display steak discoloration between the SS and NS cattle when finished on a wet corn gluten feed based diet ($P = 0.01$), but no difference between either supplementation strategy in the DGF finishing diet ($P = 0.95$). These differences in discoloration are substantial considering the time it takes for beef that is exported to reach export markets. Furthermore, while retailers may do an exceptional job managing their retail case, ensuring fresh beef is sold before it becomes discolored, the time it may take the consumer to finally utilize the beef must also be considered. The HW winter supplementation strategy increased average retail discoloration 15% compared to LW supplementation (17.9 and 15.5% respectively; $P < 0.01$). The winter supplementation

effect is further explained through the interaction between winter supplementation and retail display (Table 2; $P = 0.57$), where throughout d 0 – 4 there is no significant difference ($P \geq 0.20$) between HW and LW. However, from d 5 – 7 the steaks from HW treatment experienced a greater rate of discoloration than LW ($P \leq 0.09$). There was a tendency for winter supplementation to interact with both aging period and retail display ($P = 0.14$), with no differences d 0 – 3. However, beginning on retail d 4, both aging 21 d and HW supplementation increase ($P < 0.01$) the amount of discoloration throughout the rest of the simulated retail display. Thus, feeding DGS prior to the finishing phase was not cumulative in impacting the color stability and overall shelf life of the retail beef when cattle were finished using DGS. When they were finished without DGS, however, supplementation of DGS during the summer was detrimental to color stability.

Beef color is the most important aspect of beef sales since consumer's associate color with quality and freshness (Faustman and Cassens, 1990). Previous studies have shown a linear increase in the discoloration of beef as inclusion of DGS is increased in beef cattle finishing diets (Depenbusch et al., 2009; de Mello et al 2012a). Furthermore, Roeber et al. (2005) agreed that the high inclusion of DGS (40 – 50%; DM basis) in finishing diets could negatively impact discoloration of strip loin steaks, but reported that no detrimental effects occurred with low to moderate inclusion (10 – 25%). In the present study, the inclusion of DGS at 40% (DM basis) of the finishing diet increased discoloration as soon as d 4 and d 6 during a simulated retail case display for steaks aged 21 and 7 d which is in agreement of the previous studies and is not unique. However, there is little knowledge on the use of DGS prior to feedlot entry and its effects on meat

quality. Leupp et al. (2009) evaluated the effects of feeding 30% DGS (DM basis) in a 65% concentrate growing diet fed for 57 days and observed reductions in b* values but no effect on a* values and only tended to reduce L* values. Leupp et al. (2009) also included DGS in the final finishing diet at 30% (DM basis) and reported reductions in a* values but no other color measurement differences due to DGS inclusion. Considering that a* values are highly correlated with visual appearance scores (Zerby et al., 1999), the study conducted by Leupp et al. (2009) would appear to indicate that inclusion of DGS in the finishing diet impacts color stability more than when DGS is fed prior to finishing. The present study is in agreement with that conclusion as DGS inclusion in the finishing diet overpowered any effects prior DGS supplementation may have had, but in finishing diets absent of DGS prior supplementation effects were evident. Thus, the finishing diet composition determined the overall outcome of DGS supplementation prior to finishing.

Fatty Acid Profile

Fatty acid profiles and fat percentages for feed ingredients supplemented and fed to heifers throughout the yearling production system are reported in Table 4. Fat percentages of the DGS fed during the production system were 11.05, 9.04, and 11.53% fat (DM basis) for the winter, summer and finishing production phases respectively. The wet corn gluten feed used in the finishing phase to act as a low fat control for the effects DGS has on meat quality contained 2.30% fat. Vander Pol et al. (2009) reported that a portion of the corn oil, or fat, found in DGS is protected from rumen biohydrogenation where unsaturated fatty acids become more saturated with hydrogens forming MUFA or SFA. The process of centrifuging thin stillage during the production of DGS removes

"free fat" that would otherwise be hydrogenated in the rumen. Thus it would be expected that the removal of oil from DGS would have only minimal impacts on meat quality since it is the bound and protected fat that is the believed cause of most of the meat quality issues (Domenech et al., 2014a; 2014b).

Analyzing steak fatty acid profiles on the basis of percent fat content, there was a three way interaction for concentrations of 18:1 and total MUFA and SFA concentration between winter supplementation, summer supplementation, and finishing diet composition (P = 0.05 and 0.06, 0.08, respectively; Table 4). Concentrations of 18:1 were reduced by SS summer treatment when cattle received the LW winter and CGF finishing treatments (P = 0.04), however there were no differences within those receiving the HW winter and CGF finishing treatment. Steaks contained increased amounts of 18:1 from the CGF compared to the DGF finishing treatments ($P < 0.01$). The concentration of total MUFA within steaks was not different due to either finishing diet or supplementation level within the HW winter treatments ($P > 0.50$). However, within the LW winter treatment, the DGF finishing treatment experienced an increase of MUFA due to the SS summer treatment (P= 0.08) and within the CGF finishing treatment it was just the opposite effect as SS summer treatment decreased the MUFA concentration (P = 0.06). The authors have no plausible reason to explain these results, however. Concentrations of SFA was not different within the HW winter treatment of either finishing diet ($P > 0.54$). However, within the DGF finishing diet and LW winter - summer SS treatment strategy reduced total SFA concentrations (P = 0.09), while within the CGF finishing diet and LW winter treatment summer SS increased the total amount of SFA (P = 0.06).

Summer supplementation and finishing diet composition interacted with concentrations of 18:0 ($P = 0.06$; Table 5). Within CGF finishing diet there were no differences between SS and NS summer supplementation ($P = 0.39$), however summer SS reduced 18:0 concentrations compared to NS within the DGF finishing diet ($P = 0.08$). There was a trend ($P = 0.15$) for an interaction between summer supplementation and finishing diet composition for concentration of 17:1, with HW during winter increasing concentrations within the CGF finishing diet ($P = 0.05$), but no effect within the DGF diet ($P = 0.50$).

A trend for a winter supplementation by summer supplementation interaction was observed for the concentrations of 17:0 and 20:4 ($P = 0.14$ and 0.10, respectively; data not shown), There were no differences in 17:0 within the LW winter treatment ($P = 0.95$), but the summer SS treatment within the HW winter treatment reduced the concentration of 17:0 ($P = 0.05$). Concentrations of 20:4 were not different within the summer SS treatment ($P = 0.62$), however winter HW treatment reduced concentrations of 20:4 compared to LW within the NS summer strategy ($P = 0.06$).

There was only a finishing diet composition main effect ($P < 0.01$) on concentrations of 18:2 and total PUFA (Table 6). Concentrations of 18:2 were greater in steaks from the DGF treatment compared to from the CGF (3.81 and 2.87%, respectively; $P < 0.01$). Considering 18:2 makes up such a large proportion of the total PUFA concentration, the results were similar in that DGF contained more PUFA than CGF (4.56 and 3.62%, respectively; $P < 0.01$). Finishing diet also affected concentrations of 14:0, 15:0, 16:1, 17:0, 17:1, 18:1*t*, and 18:1*v* (Table 6). Concentrations of 14:0, and 18:1*t*

were increased in steaks from the DGF finishing treatment compared to CGF ($P = 0.01$ and < 0.01, respectively). However, the DGF treatment reduced concentrations of 15:0, 16:1, 17:0, 17:1, and 18:1*v* ($P = 0.08$, < 0.01, < 0.01, < 0.01, and < 0.01, respectively).

Winter supplementation influenced concentrations of 15:1, 16:1, 18:0, and 20:0 with HW increasing concentrations of 16:1 and 20:0 ($P = 0.02$ and 0.09, respectively), however decreased concentrations of 15:1 and 18:0 (P =0.03 and 0.04, respectively). There was a tendency for SS summer treatment to increase concentrations of 14:1 compared to NS ($P = 0.10$). There was no effect of dietary treatment on the concentrations of 16:0 ($P > 0.16$).

There was a winter supplementation by finishing diet interaction for total fat content of steaks ($P < 0.01$) with no differences between LW and HW in fat content of the DGF finishing treatment, however within the CGF finishing diet, LW steaks had a lower fat content than HW (5.94 and 7.38%, respectively; $P < 0.01$; Table 7). Therefore fatty acid profiles were also analyzed on a g/ - 100 g of muscle tissue basis. When analyzed in this fashion there was a winter supplementation by finishing diet interaction for concentrations of 18:2 and total PUFA (Table 6; $P = 0.02$ and 0.01 g/ - 100 g muscle, respectively) of strip loin steaks. Concentration of 18:2 was not different in DGF treatment ($P = 0.42$), however, steaks from the LW winter treatment contained less 18:2 than steaks from the HW treatment (0.17 and 0.20 g / - 100 g muscle, respectively; $P < 0.01$). Total PUFA concentrations effects were identical to that of 18:2 with no effects of winter supplementation within the DGF finishing treatment ($P = 0.32$), but PUFA

concentration was less for LW compared to the HW winter supplementation strategy (0.21 and 0.25 g / 100 g muscle, respectively; $P < 0.01$).

These data would agree with previous research reporting the effects of DGS inclusion in beef finishing diets on fatty acid profiles, specifically the increase in the concentrations of 18:2 and total PUFA while concentrations of total SFA remains unaltered with increased inclusion of DGS (Gill et al., 2008; Depenbusch et al., 2009, de Mello et al., 2012b). The increased concentrations of 18:2 and PUFA can be explained by the greater fat total content of DGS, which also has a greater digestibility due to the increased unsaturated fatty acid content compared to both corn and wet corn gluten feed (Table 4; Zinn et al., 2000; Lock et al., 2005; Vander Pol et al., 2009). There is a large amount of attention given to the concentrations of PUFA , specifically that of 18:2, due to the effects of increasing oxidation rates and potentially the development of off-flavors in beef that has under gone retail display due to an increase in oxidation (Calkins and Hodgen, 2007).

Distillers grains supplementation during backgrounding has the potential to impact the fatty acid profile of beef. The extent and degree of such alterations is dependent primarily on the final finishing diet that cattle consume. These data also provide some evidence to suggest that the level of DGS supplementation has some implications on fatty acid profile of beef.

Lipid Oxidation

The expected effects of aging ($P < 0.01$), days of retail display ($P < 0.01$), and the interaction of aging and retail display ($P < 0.01$; Table 8) on TBARS correspond to the percent discoloration data as with increased aging and increased retail display there is an increase the amount of oxidation that occurs. However, in the present study there were no significant differences ($P > 0.15$) in lipid oxidation due to any dietary treatments or possible interactions.

Previous research has shown linear increase in TBA values for beef from cattle fed DGS during finishing as retail display days increases (de Mello et al., 2012a). Similarly, Koger et al. (2010) observed increased lipid oxidation in ground beef from cattle fed 40% (DM basis) DGS in the finishing diet compared to cattle fed a dry rolled corn control. The present study, however, appears to contradict those findings and suggests that the inclusion of DGS in the finishing diet would not negatively impact lipid oxidation of beef ($P = 0.69$). Furthermore, these data also would indicate that the strategy of supplementing DGS in either the winter backgrounding or summer grazing phases would not be detrimental to oxidation of lipids in the eventual beef from cattle that would undergo such a system ($P > 0.84$). However, as discussed previously concerning color score data, there was an increased oxidation of color pigments due to an increased supplementation and inclusion of distillers grains. The increase oxidation of pigments caused an increase in the rate of steak surface discoloration, thus reducing its viable self-life. It is unclear why the current experiment did not demonstrate lipid oxidation from DGS fed cattle, even though there was an increase in PUFA concentration when DGS

was included in the finishing diet. Depenbusch et al. (2009) reported that a greater PUFA: SFA ratio did not increase the degree lipid oxidation, but that the total concentration of PUFA would likely be more detrimental. Lipid oxidation is of concern not only due to potential to increase discoloration but several studies have reported off- flavors developing in beef that has undergone retail display and increased amounts of oxidation (Calkins and Hodgen, 2007). However, no taste panels were conducted to support or refute the oxidation data with flavor alterations in steaks from this study.

Warner – Bratzler Shear Force

In the current study, WBSF data revealed the expected decreased ($P < 0.01$) in shear force as aging increases from 7 to 21 d (Table 9). There was not a three way interaction between winter supplementation, summer supplementation and finishing diet composition for WBSF ($P = 0.52$). While all samples were relatively tender, cattle supplemented with DGS during the summer were slightly, but significantly, less tender (Table 7) than cattle that were not supplemented (3.46 and 3.09 kg, respectively; $P =$ .016). This effect was most noticeable when cattle were finished on DGS. Although significant, the magnitude of the tenderness is not likely to be noticed by or meaningful to consumers. No further effects or interactions were observed for winter supplementation, summer supplementation, or finishing diet composition dietary treatments or interactions with aging period ($P > 0.16$) in the present study.

The results of the current study would agree with previous studies reporting no differences in WBSF between steaks from cattle fed corn control diets or various levels of DGS (Roeber et al., 2005; Kinman et al., 2011; de Mello et al., 2012a). These data in

combination with the present study allow for the conclusion that the inclusion of DGS in the finishing diet does not profoundly impact the tenderness of beef steaks, but the use of DGS prior to finishing could potentially cause reduced steak tenderness. Contrary to these studies however, Depenbusch et al. (2009) used a taste panel survey to report a linear increase in perceived tenderness and a decrease in the perceived amount of connective tissue as inclusion of DGS increased from 0 to 75% (DM basis) in finishing diets. However, no taste panels were conducted to support or refute the WBSF data in the current study.

CONCLUSION

Finishing diet used at the end of the yearling production system determined the overall effects prior DGS supplementation during the winter backgrounding and summer grazing phases had on meat quality attributes. When DGS were included in the finishing diet, the known effects of DGS inclusion in the finishing diet overpowered any effects of prior supplementation, but supplementation was not cumulative to its effects. However, when DGS was not included in the finishing diet, prior DGS supplementation increased concentrations of PUFA, most notably 18:2, causing increases in the rate of discoloration and overall reduction in shelf life.

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Table 1. Effects of summer supplementation and finishing diet on average percent discoloration across 7 days of retail display for strip steaks aged 7 and 21 days from heifers fed distillers grains throughout a yearling beef production system.

	DGF[1]		CGF			*P*-value		
	SS[2] n = 22	NS n = 24	SS n = 24	NS n = 25	SEM	Summer	Finish	Summer x Finishing[3]
Discoloration[4]	16.73[b]	12.88[a]	18.55[bc]	18.61[c]	0.77	0.014	< 0.01	0.014

[a,b,c]Means in the same row having different superscripts are significantly different at $P \leq 0.10$.

[1]Heifers received a finishing diet consisting of either 40% wet corn gluten feed (Sweet Bran; CGF) or 40% modified distillers grains(DGF).

[2]Heifers received no supplement (NS) or dried distillers grains supplement at 0.6% of body weight (SS) during summer grazing period.

[3]Interaction between summer supplementation level and composition of finishing diet.

[4] Percentage of muscle area estimated to be discolored (0% = no discoloration; 100% = fully discolored).

Table 2. Effects of winter supplementation and retail display on percent discoloration across 7 days of retail display for strip steaks aged 7 and 21 days from heifers fed distillers grains throughout a yearling beef production system.[1]

Retail Day	HW[2] n = 48	LW n = 47	SEM	*P*-value[3]
0	0.39	0.30	2.15	0.97
1	0.39	0.37	2.15	0.99
2	0.61	0.51	2.15	0.96
3	1.63	2.37	2.15	0.73
4	10.76	7.99	2.15	0.20
5	25.53	21.84	2.15	0.09
6	44.86	39.10	2.15	<0.01
7	58.88	51.58	2.15	<0.01

[a,b,c]Means in the same row having different superscripts are significantly different at $P \leq 0.10$.
[1]Percentage of muscle area estimated to be discolored (0% = no discoloration; 100% = fully discolored).
[2]Heifers received Low (0.91 kg; LW) or High (2.3 kg; HW) level of modified distillers grains supplementation during winter corn stalk grazing period.
[3]Interaction between winter supplementation level and retail display.

Table 3. Effects of summer supplementation and finishing diet on average percent discoloration across 7 days of retail display for strip steaks aged 7 and 21 days from heifers fed distillers grains throughout a yearling beef production system.

	DGF[1]		CGF			*P*-value		
	SS[2] n = 22	NS n = 24	SS n = 24	NS n = 25	SEM	Summer	Finish	Summer x Finishing[3]
Discoloration[4]	16.73[b]	12.88[a]	18.55[bc]	18.61[c]	0.77	0.014	< 0.01	0.014

[a,b,c]Means in the same row having different superscripts are significantly different at $P \leq 0.10$.

[1]Heifers received a finishing diet consisting of either 40% wet corn gluten feed (Sweet Bran; CGF) or 40% modified distillers grains(DGF).

[2]Heifers received no supplement (NS) or dried distillers grains supplement at 0.6% of body weight (SS) during summer grazing period.

[3]Interaction between summer supplementation level and composition of finishing diet.

[4] Percentage of muscle area estimated to be discolored (0% = no discoloration; 100% = fully discolored).

Table 4. Fatty acid profile and fat percent of feed ingredients fed to heifers fed distillers grains throughout a yearling beef production system[1]

Item	Winter MDGS	Summer DDGS	Finish MDGS	Wet corn gluten feed	High-moisture corn	Wheat Straw
16:0	15.24	14.44	14.92	21.18	11.84	20.05
18:0	2.11	2.05	2.12	3.99	2.13	8.77
18:1	25.69	26.28	27.57	25.91	34.17	53.88
18:2	54.19	55.39	53.21	46.24	50.58	17.30
18:3	1.72	1.85	1.70	2.69	1.29	<0.01
Unknown	1.06	<0.01	0.47	<0.01	<0.01	<0.01
PUFA[2]	55.90	57.24	54.91	48.92	51.86	17.30
MUFA	25.69	26.28	27.57	25.91	34.17	53.88
SFA	17.35	16.49	17.05	25.17	13.97	28.82
Fat, %	11.05	9.04	11.53	2.53	3.77	0.77

[1]Relative proportions of all peaks observed by gas chromatography.
[2]PUFA includes 18:2 and 18:3

Table 5. Effect of finishing diet on fatty acid profile percent of steaks from heifers fed distillers grains throughout a yearling beef production system

	HW[1]				LW								
	SS[2]		NS		SS		NS						
Item	DGF[3] n = 11	CGF n = 12	DGF n = 12	CGF n = 13	DGF n = 11	CGF n = 12	DGF n = 12	CGF n = 12	SEM	Winter	Summer	Finish	Int[4]
Fatty Acid Profile													
16:0	24.40	24.36	24.65	24.67	23.81	24.90	24.52	23.51	0.57	0.38	0.93	0.97	0.17
18:0	14.50^{bcd}	14.00^{d}	15.34^{abc}	14.26^{cd}	15.05^{abcd}	15.68^{ab}	16.24^{a}	14.47^{bcd}	0.59	0.04	0.50	0.09	0.26
18:1	35.95	39.84	35.41	38.59	36.58	37.06	34.83	39.66	0.93	0.51	0.71	<0.01	0.05
18:2	3.90	2.89	3.83	2.76	3.70	2.86	3.92	2.97	0.21	0.97	0.96	<0.01	0.94
PUFA	4.70	3.67	4.52	3.39	4.42	3.66	4.59	3.76	0.26	0.83	0.80	<0.01	0.97
MUFA	46.26^{abcd}	48.65^{a}	45.46^{bcd}	47.69^{ab}	46.82^{abc}	45.34^{cd}	44.21^{d}	48.02^{a}	1.05	0.21	0.55	<0.01	0.06
SFA	48.11^{abc}	47.11^{c}	49.04^{abc}	48.02^{bc}	47.95^{bc}	50.43^{ab}	50.56^{a}	47.57^{c}	1.11	0.17	0.60	0.41	0.08
PUFA:SFA	0.098	0.078	0.094	0.071	0.092	0.074	0.092	0.079	<0.01	0.79	0.65	<0.01	0.58
Fat%	6.31	6.99	6.08	7.77	7.18	6.04	6.34	5.85	0.48	0.18	0.71	0.58	0.78

[a,b,c,d]Means in the same row having different superscripts are significantly different at $P \leq 0.10$. Lower score indicates a tenderer steak.

[1]Heifers received Low (0.91 kg) or High (2.3 kg) level of distillers grains supplementation during winter corn stalk grazing period.

[2]Heifers received no supplement or dried distillers grains supplement at 0.6% of body weight during summer grazing period

[3]Heifers received a finishing diet consisting of either 40% wet corn gluten feed (Sweet Bran; Cargil) or 40% distillers grains.

[4]Winter, summer and finishing phase's interaction.

Table 6. Effect of finishing diet on fatty acid profile percent of steaks from heifers fed distillers grains throughout a yearling beef production system[1]

Fatty acid	Finishing diet[2]		SEM	*P* -value
	DGF n = 46	CGF n = 49		
14:0	2.58	2.39	0.05	0.01
14:1	0.58	0.60	0.02	0.54
15:0	0.50	0.55	0.02	0.08
15:1	0.62	0.65	0.03	0.35
16:0	24.35	24.36	0.28	0.97
16:1	2.77	3.11	0.06	<0.01
17:0	1.48	1.77	0.03	<0.01
17:1	0.97	1.29	0.02	<0.01
18:0	15.28	14.60	0.29	0.09
18:1t	3.31	1.20	0.18	<0.01
18:1	35.69	38.79	0.45	<0.01
18:1v	1.72	1.88	0.04	<0.01
18:2	3.81	2.87	0.10	<0.01
20:0	4.58	4.65	0.29	0.85
20:4	0.70	0.71	0.03	0.85
Unknown	1.00	0.77	0.06	<0.01
PUFA[3]	4.56	3.62	0.13	<0.01
MUFA	45.69	47.43	0.51	0.02
SFA	48.91	48.29	0.55	0.41

[1]Relative proportions of all peaks observed by gas chromatography.

2Heifers received a finishing diet consisting of either 40% wet corn gluten feed (Sweet Bran, Cargil) or 40% modified distillers grains.

[3]PUFA includes 18:2, 18:3 20:2, 20:3, and 20:4.

Table 7. Effects of winter supplementation and finishing diet on muscle weight percent adjusted fatty acid profile and percent fat of steaks from heifers fed distillers grains throughout a yearling beef production system.[1]

	DGF[2]		CGF			*P*-value		
Item	HW[3] n = 23	LW n = 23	HW n = 25	LW n = 24	SEM	Winter	Finish	W x F[4]
14:0	0.16[a]	0.17[a]	0.18[a]	0.14[b]	0.01	0.15	0.37	0.01
14:1	0.04[b]	0.04[b]	0.05[a]	0.03[b]	<0.01	0.03	0.54	0.02
15:0	0.03	0.03	0.04	0.03	<0.01	0.10	0.31	0.11
15:1	0.03[b]	0.04[a]	0.04[a]	0.04[a]	<0.01	0.50	0.19	0.04
16:0	1.53[b]	1.64[ab]	1.80[a]	1.44[b]	0.09	0.15	0.65	<0.01
16:1	0.18[b]	0.18[b]	0.24[a]	0.18[b]	0.01	0.02	0.01	0.01
17:0	0.10[b]	0.10[b]	0.13[a]	0.10[b]	<0.01	0.20	<0.01	<0.01
17:1	0.06[c]	0.07[bc]	0.10[a]	0.07[b]	<0.01	0.07	<0.01	<0.01
18:0	0.93[ab]	1.06[a]	1.04[a]	0.90[b]	0.06	0.86	0.65	0.02
18:1t	0.22	0.22	0.09	0.06	0.02	0.36	<0.01	0.41
18:1	2.21[b]	2.43[b]	2.91[a]	2.30[b]	0.14	0.17	0.05	<0.01
18:1v	0.10[b]	0.12[b]	0.14[a]	0.11[b]	<0.01	0.32	0.06	<0.01
19:0	0.01	0.01	<0.01	<0.01	<0.01	0.72	<0.01	0.51
18:2	0.23[a]	0.25[a]	0.20[b]	0.17[c]	<0.01	0.20	<0.01	0.02
20:0	0.26	0.30	0.29	0.29	0.02	0.44	0.60	0.26
20:4	0.04	0.04	0.05	0.04	<0.01	0.80	0.20	0.13
Unknown	0.06	0.05	0.05	0.04	<0.01	0.20	0.15	0.51
PUFA[5]	0.28[ab]	0.29[a]	0.25[b]	0.21[c]	0.01	0.25	<0.01	0.01
MUFA	2.84[b]	3.10[b]	3.58[a]	2.80[b]	0.18	0.13	0.21	<0.01
SFA	3.02[bc]	3.32[ab]	3.49[a]	2.90[c]	0.16	0.35	0.86	<0.01
Fat, %	6.20[bc]	6.76[ab]	7.38[a]	5.94[c]	0.33	0.18	0.58	<0.01

[a,b,c]Means in the same row having different superscripts are significantly different at $P \leq 0.10$.
[1]Relative proportions of all peaks observed by gas chromatography (g / 100 g muscle tissue).
[2]Heifers received a finishing diet consisting of either 40% wet corn gluten feed (Sweet Bran, Cargil) or 40% modified distillers grains.
[3]Heifers received Low (0.91 kg) or High (2.3 kg) modified distillers grain supplement during winter corn stalk grazing.
[4]Interaction between winter supplementation level and finishing diet composition.
[5]PUFA includes 18:2, 18:3 20:2, 20:3, and 20:4.

Table 8. Effects of retail display and aging on amount of malondialdehyde (mg/kg), a measure of oxidative rancidity, of strip steaks from heifers fed distillers grains throughout a yearling beef production system.

Day of retail display[1]	7- Day age[2]	21-Day age
0	1.45[a]	2.02[a]
4	3.22[b]	5.33[b]
7	5.96[c]	7.72[c]

[a,b,c]Means in the same column having different superscripts are significantly different at $P \leq 0.10$
[1]Day removed from the simulated retail display following the assigned aging period.
[2]Duration of aging period prior to steak fabrication, packaging, and simulated retail display.

Table 9. Tenderness of steaks from heifers fed distillers grains throughout a yearling beef production system.

	DGF[1]				CGF								
	HW[2]		LW		HW		LW			*P*-Value			
	SS[3] n = 11	NS n = 12	SS n = 11	NS n = 12	SS n = 12	NS n = 13	SS n = 12	NS n = 12	SEM	Winter	Summer	Finish	Int[4]
WBSF, kg	3.24[bc]	3.24[bc]	3.46[a]	3.09[c]	3.36[bc]	3.18[bc]	3.44[ab]	3.38[ab]	0.09	0.167	0.016	0.168	0.052

[a,bc]Means in the same row having different superscripts are significantly different at $P \leq 0.10$. Lower score indicates a tenderer steak.
[1]Heifers received a finishing diet consisting of either 40% wet corn gluten feed (Sweet Bran, Cargil) or 40% distillers grains.
[2]Heifers received Low (0.91 kg) or High (2.3 kg) level of distillers grains supplementation during winter corn stalk grazing period.
[3]Heifers received no supplement or dried distillers grains supplement at 0.6% of body weight during summer grazing period.
[4]Winter, summer and finishing phase's interaction.

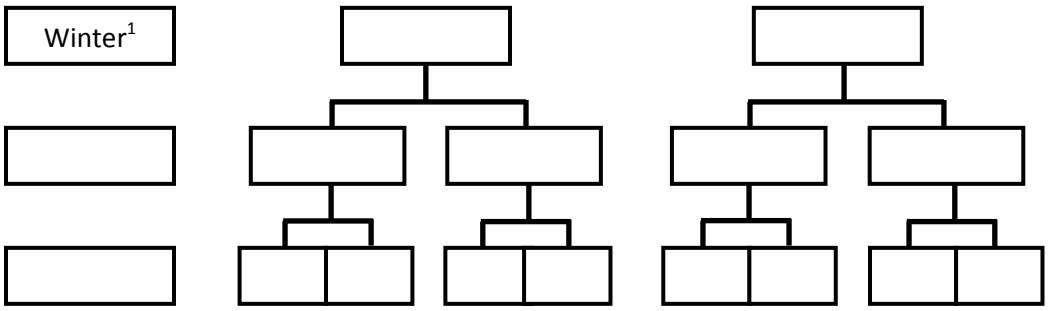

Figure 1. Treatment design for heifers fed distillers grains throughout a yearling beef production system.

[1]Heifers received 0.91 kg DM (LW) or 2.3 kg (HW) level of distillers grains supplementation during winter corn stalk grazing period.

[2]Heifers received no supplement (NS) or a distillers grains supplement (SS) at 0.6% of body weight during summer grazing period.

[3]Heifers received a finishing diet consisting of either 40%wet corn gluten feed (Sweet Bran, Cargil, CG) or modified 40% distillers grains (DG).

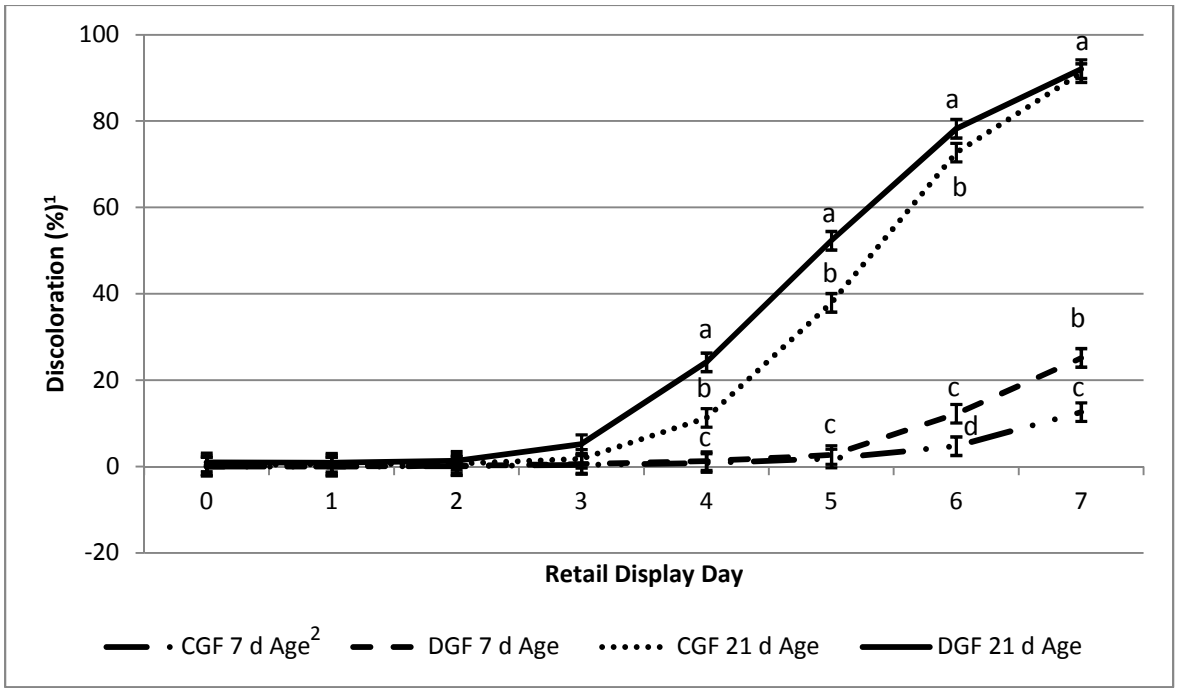

Figure 2. Effect of finishing diet, retail display and aging on discoloration of strip steaks from heifers fed distillers grains throughout a yearling beef production system.

[a,b,c]Means in the same day of retail display having different superscripts are significantly different at $P \leq 0.10$.

[1] Percentage of muscle area estimated to be discolored (0% = no discoloration; 100% = fully discolored).

[2] Heifers received a finishing diet consisting of either 40% wet corn gluten feed (Sweet Bran, Cargil; CGF) or 40% modified distillers grains (DGF), and steaks were then aged for 7 or 21 days prior to the simulated retail display.

CHAPTER IV: EFFECTS OF SUPPLEMENTION OF OMNIGEN – AF WITH OR WITHOUT RACTOPAMINE HYDROCHLORIDE ON ANIMAL PERFORMANCE AND BEEF CARCASS CHARACTERISTICS OF FEEDLOT STEERS[1]

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ABSTRACT: Crossbred steers (n = 336; initial BW = 309 ± 22 kg) were utilized in a feedlot finishing trial in a 3 x 2 factorial complete randomized block design with the objective of identifying any possible interaction between OmniGen – AF (OM), a commercial feed additive containing B- complex vitamins and live yeast cells, and ractopamine hydrochloride (RAC). Factors were duration of OM supplementation (0, 28, or 56 d) during the final stage of feedlot production at 4 g / 45.5 kg BW and supplementation of RAC at 300 mg· steer-1d-1 for the last 28 d of finishing (RAC) or no beta agonist supplementation (NORAC). Steers were blocked by BW, stratified, and assigned randomly within block to pen (n = 42; 8 steers / pen). Ultrasound data measurements of rump fat thickness, 12^{th} rib fat thickness, LM area, and intramuscular fat were collected on each steer 56 and 1 d prior to harvest and the difference between these time points was calculated. The day of harvest HCW were recorded. After a 48 – h chill, 12^{th} rib fat depth, LM area, and marbling score were recorded. Data were analyzed using the Glimmix Procedure of SAS as a completely randomized block design with pen was the experimental unit and block treated as a random effect. There were no OM by RAC interaction observed in this study for any of the feedlot performance, carcass characteristics or ultrasound variables measured ($P > 0.42$). There was no significant effect of OM supplementation on any feedlot performance or carcass characteristics ($P \geq 0.10$). Over the entire feeding period, steers supplemented RAC experienced a 0.5 kg/ d increase in ADG (1.81 and 1.76 kg/ d; $P = 0.02$), resulting in 10.0 kg greater FBW (625 and 615 kg; $P < 0.01$) and a 7.0 kg heavier carcass (394 and 387 kg; $P < 0.01$) compared to steers that received NORAC. Analysis of ultrasound time point differences reveals

RAC steers experienced a 2.1 cm^2 greater increase in steer's LM area (6.6 and 4.6 cm^2, respectively; $P = <0.01$) and reduction in the increase of intramuscular fat percentage (0.26 and 0.48%, respectively; $P = 0.02$) compared to NO RAC. These data would suggest that there is no effect on overall steer feedlot performance or carcass characteristics due to Omnigen – AF supplementation during the final 56 d of feedlot finishing.

Keywords: Beef, Omnigen – AF, ractopamine hydrochloride

INTRODUCTION

Ractopamine hydrochloride (RAC; Elanco Animal Health; Greenfield, IN) is a beta-adrenergic agonist administered to beef cattle via feed supplementation during the last 28 – 42 days of the finishing period at a rate of 8.2 to 24.6 g/ton and 70 to 430 mg/ animal/ daily DMI with no withdrawal period (FDA, NADA 141-221, 2003). As the animal reaches the market endpoint, the rate of muscle deposition slows, but the rate of fat deposition increases. Supplementing cattle with ractopamine hydrochloride reduces the rate at which body fat is deposited, allowing for continued increase in the proportion of muscle growth through increasing muscle fiber hypertrophy (Beermann, 2002; Mills 2002a). Supplementing cattle with ractopamine hydrochloride during the final 28-40 days of the feedlot finishing period increases ADG, G:F, dressing percentage HCW, and FBW, while having little to no impact on DMI, 12^{th} rib fat thickness or marbling characteristics (Gruber et al. 2007; Quinn et al., 2008; Boler et al., 2012).

OmniGen – AF is commercial feed additive that provides a supplemental source of B- complex vitamins and live yeast cells that are marketed as providing an immune system boost to the animal (Prince Agri Products, Inc., 2006.). OmniGen – AF supplementation increased concentrations of both L – selectin and IL-1β in lambs that experienced a pathogen challenge (*Aspergillus fumigatus*; > 1 million spores/ g; Wang et al., 2004). Chapman et al. (2005) evaluated the effects of supplementing OmniGen – AF at 56 g / hd / d in Holstein cows on milk production and persistence of milk yield during a 60 d field trial. Daily milk production was increased from 33.4 to 34.1 kg/ hd / d by supplementing Omnigen – AF while also increasing the persistence of milk yield. In several studies were feedlot cattle were exposed to an endotoxin challenge (lipopolysaccharide, LPS), researchers reported an ability of OmniGen – AF to prime the immune system prior to the LPS challenge allowing the cattle to a display stronger acute phase response to the LPS challenge while persevering energy stores in the body (Burdick 2012a et al. 2012, Vann et al., 2012, Burdick Sanchez et al., 2014b).

There is currently no literature on the combination as to the effects of supplementing OmniGen- AF during the final phase of feedlot production. Thus the objectives of this study were to evaluate any possible interactions to the effects of supplementing OmniGen – AF during the final 0, 28, or 56 days of the feedlot finishing phase with or without supplemented RAC on feedlot steer performance, carcass characteristics, and the change in body composition over the final 56 days via ultrasound imaging.

MATERIALS AND METHODS

All procedures and facilities related to live animals for this study were approved by the Institutional Animal Care and Use Committee of the University of Nebraska.

Animal Management

Crossbred steers (n = 336; initial BW = 309 ± 22 kg) were utilized in a feedlot finishing trial at the University of Nebraska Panhandle Research Feedlot (PREC) near Scottsbluff, Nebraska in a 3 x 2 factorial completely randomized block design. The first factor was the duration of OmniGen – AF (Prince Agri Products, Inc.; Quicny, IL) supplementation (4 g / 45.5 kg BW) being the last 0, 28, or 56 days of the finishing period. The second factor was supplementation of ractopamine hydrochloride (**RAC**; Elanco Animal Health; Greenfield, IN) at 300 mg/ steer / day for the last 28 days of finishing (R) or no beta agonist supplementation (N). The above treatment design provided a total of 6 experimental treatments, 3 with a beta agonist (0R, 28R, 56R) and 3 without a beta agonist (0N, 28N, 56N).

Steers were purchased from auction markets in Scottsbluff, Nebraska on November 11, 2013 and St. Ogne, South Dakota November 22, 2013. On arrival to the PREC, steers were individually identified (panel tag, metal clip), vaccinated with Express 5 (Boehringer Ingelheim; St. Joeseph, MO) and Vision 7 Somnus (Merck Animal Health; Summit, NJ), treated for parasites with Ivomec (Merial Limited; Duluth, GA), and branded. Steers were revaccinated with Express 5 when initial ultrasound data was collected 56 days prior to the targeted marketing date of each BW block. Steers were limit fed a diet consisting of 45% ground alfalfa hay, 35% wet beet pulp, and 20% of wet

distillers grains plus solubles (WDGS; DM basis) for a minimum of 5 d prior to the start of the experiment. Three – day BW measurements were recorded on day -1, 0 and 1 of the experiment, were averaged, and used as the initial BW for the experiment to reduce variation associated with gastrointestinal tract fill (Stock et al., 1983; Watson et al., 2013). Steers were blocked by the initial BW into heavy, medium, and light BW blocks, stratified by BW and assigned randomly within block to pen for a total of 42 pens (8 steers / pen). Pen was then assigned randomly to one of the six treatment combinations described above. Steers were implanted with Revalor® – XS (Merck Animal Health) on day -1. Steers were adapted to a finishing diet via four step – up diets that replaced alfalfa hay with dry – rolled corn (DRC). Step – up diets were fed 3, 4, 7, and 7 days; respectively (Table 1), so that by d 22 of the trial steers were fed the common finishing diet. Steers were fed a finishing diet consisting of 54% DRC, 25% WDGS, 15% corn silage, 6% supplement (DM basis; Table 1). All steers were fed a supplement provided via micomachine (Model 271 Weigh and Gain Generation 7; Animal Health International, Greely, CO) to provide 360 mg / hd / daily Rumensin® (Elanco Animal Health; DM basis) and 90 mg/ steer daily of Tylan (Elanco Animal Health). OmniGen – AF supplementation (4 g / 45.5 kg BW) was administered through topdressing the delivered finishing diet beginning 56 (56R and 56N) or 28 (28R and 28N) d prior to the targeted marketing date of each BW block during the remainder of the finishing period. The topdress consisted of 50 g OmniGen – AF and 100g fine ground corn carrier (DM basis) fed to achieve 4 g OmniGen – AF / 45.5 kg steer BW. Pens designated to not receive OmniGen – AF supplementation (0R and 0N) also received a topdress of fine

ground corn as a control. Pens designated to treatments that received a beta agonist (0R, 28R, and 56R) were supplemented RAC (300 mg/ steer daily) via micromachine beginning 28 d prior to the targeted market date of each BW block and lasted throughout the remainder of the finishing period. Steers had ad libitum access to fresh clean water and their respective diets. Steers were fed once daily for the duration of the study. Diet samples were sent to Servi Tech Labs (Hastings, NE) for analysis.

Ultrasound Data Collection

Ultrasound data measurements of rump fat thickness (RUMP), 12th rib fat thickness (RIB), LM area, and intramuscular fat (IMF) were collected on each steer 56 d prior (Initial) to the targeted marketing date of each BW block and then again 1 d prior (Final) to steers being harvested. Individual steer BW was also collected at each ultrasound time point. The differences between final and initial ultrasound data were then calculated to determine any body composition change due to dietary treatments imposed.

Carcass Data Collection and Calculations

Steers in the heavy and medium BW blocks were harvested on d 167 and the light BW block was harvested on d 194. Cattle were not fed the morning prior to being shipped, and were fed ad libitum the d prior to shipment. Carcass data were collected by Diamond T Livestock Services (Yuma, CO). Hot carcass weight, and liver scores were recorded the day of harvest. After a 48 – hour chill, 12th rib fat depth, LM area, and marbling score (where 300 = Slight^{0}, 400 = Small^{0}) were recorded. Carcass adjusted final BW, used in calculation of ADG and G:F, was calculated from HCW using a common

dressing percentage of 63% to minimize errors associated with gastrointestinal tract fill. Yield grade was calculated (USDA, 1997) from the equation

Yield Grade = 2.50 + (6.35 x fat thickness, cm) – (2.06 x LM area, cm^2) + (0.2 x KPH, %) + (0.0017 x HCW, kg)

Statistical Analysis

Feedlot performance and carcass characteristics data were analyzed using the Glimmix Procedure of SAS (SAS 9.3; SAS Institue, Inc., Cary, N. C.) as a completely randomized block design. Pen was the experimental unit and block was treated as a random effect. Model included main effects of OmniGen – AF and RAC and the interaction of OmniGen – AF and RAC. A difference in interim body weights collected 58 days prior to harvest for steers RAC treatment factor was detected ($P = 0.04$; Table 2). Therefore, 58 - day interim BW was considered as a possible covariate according to the 3 – step covariate analysis process described by Milliken and Johnson (2002). The relationship for interim BW, and the Omnigen – AF by RAC interaction was tested using independent slopes for each treatment by including the interim BW by Omnigen – AF by RAC interaction in the model statement for all feedlot performance and carcass characteristics measured. Contrast statements were included to test the independent slopes assumption. If the interactions were not significant ($P > 0.10$), and the slopes did not differ ($P > 0.10$), the Omnigen – AF term was removed from the interaction as a possible covariate and the interim BW by RAC interaction was tested as a possible covariate for the model. A contrast statement was again included to test the assumption of independent slopes. If the interaction was not significant ($P > 0.10$), and the slopes did

not differ ($P > 0.10$), a common slope model was tested through removal of the interim BW by RAC interaction term and inclusion of interim BW in the model as a covariate. If interim BW was not significant ($P > 0.10$) as a covariate, it was removed from the model. Occurrences of liver abscesses were analyzed using the Glimmix Procedure of SAS. Ultrasound data was analyzed using the Glimmix Procedure of SAS using pen as the experimental unit and block treated as a random effect. Main effects of OmniGen – AF and RAC were tested as well as the interaction of OmniGen – AF and RAC. Treatment differences for all measured steer performance, carcass characteristics, and ultrasound data were considered significant at $P < 0.05$ with tendencies noted when $P \leq 0.10$.

RESULTS AND DISCUSSION

Three steers died during the trial, all of which were from the 0NORAC treatment. One steer died of chronic respiratory disease, one died of trauma to the heart, and one died of chronic diphtheria.

Feedlot Animal Performance

There were no OmniGen – AF by RAC interaction observed in this study for any of the feedlot animal performance variables measured ($P \geq 0.42$; Table 2). Furthermore, there were also no observed significant differences in any of the feedlot performance measures due to 4 g/ 45.5 kg of OmniGen – AF supplementation ($P \geq 0.18$; Table 2). However, supplementation of RAC at 300 mg/ hd/ d for 28 d created significant differences in FBW, ADG, and G:F of feedlot steers ($P < 0.01$, 0.02, and 0.05, respectively; Table 2). Steers supplemented RAC finished with 10.0 kg greater FBW compared to NORAC steers (625 and 615 kg for RAC and NORAC, respectively; $P <$

0.01; Table 2). The increase in FBW by steers supplemented with RAC was a result of a 0.05 kg/ d increase in steer ADG compared to steers that received NORAC (1.81 and 1.76 kg/ d for RAC and NORAC, respectively; $P = 0.02$; Table 2). Considering there were no differences in DMI for any imposed treatments ($P > 0.67$; Table 2), and the increased ADG experienced by steers supplemented with RAC resulted in an improved G:F for those steers supplemented with RAC compared to those that received NORAC (0.176 and 0.171 for RAC and NORAC, respectively; $P = 0.05$; Table 2)

The feedlot performance data in the present study agree with previous research concluding that RAC increases ADG, FBW, and improves G:F with little to no impact on DMI (Gruber et al., 2007; Vogel et al., 2009; and Boler et al., 2012). Ractopamine hydrochloride supplemented at 300 mg/ steer daily during the final 28 days of feedlot finishing increased live FBW 14.6 kg compared to controls, increased ADG 54.5% (0.96 and 1.48 kg/ d for control and 300 mg/ steer daily respectively), and improved G:F 47.5% (0.095 and 0.148 for control and 300 mg/ steer daily; respectively) compared with controls (Boler et al., 2012). In the current experiment FBW was increased 10.0 kg and ADG increased 0.05 kg/d resulting in a 0.05 kg/ kg improvement in G:F for RAC over NORAC, which is consistent with the increases reported by Boler et al., (2012).

Reuter et al. (2007), supplemented 199 head of newly received crossbred heifers for 44 d with or without supplemented OmniGen – AF and Sucram C – 150 (0.68 and 26.7% supplement DM, respectively, replacing ground corn) with the supplement included at 3.0% (DM basis) of the diets. The inclusion of Sucram and OmniGen – AF in the receiving diets had no effect on heifer growth performance (ending BW, ADG, DMI,

and G:F) during the 44 d receiving period or on the 240 d feedlot growth performance (HCW, FBW, and ADG; Reuter et al., 2007). However, several studies have reported increases in the immune response to a LPS challenge in cattle supplemented OmniGen – AF (Burdick 2012a, Burdick Sanchez 2014a, Burdick Sanchez 2014b) that occurred within d 28 – 40 of the feedlot receiving period, which is when feedlot cattle would most commonly experience the greatest amount of stress and thus be immunocompromised (Edwards, 1996). In the present study, however there was no effect on any of the feedlot performance measures due to supplementation of OmniGen – AF, similar to the reports made by Reuter et al. (2007), thus indicating cattle were potentially did not experience any sort of elevated stress levels during the final 56 d of finishing due to any stress related factors, including RAC supplementation.

Carcass Characteristics

There was no OmniGen – AF by RAC interaction observed for any of the carcass characteristics measured ($P \geq 0.44$; Table 3). Furthermore, there was no effect of Omnigen – AF supplementation on HCW, LM area, calculated yield grade, marbling score, or the percentage of abscessed livers in the present study ($P > 0.18$; Table 3). However a tendency ($P = 0.10$) for Omnigen – AF supplementation to increase 12^{th} rib fat thickness was observed (1.34, 1.45, and 1.41 cm, for 0, 28, 56 days of Omnigen – AF supplementation, respectively). Supplementation of RAC increased HCW and LM area of steers. Carcasses from steers that received RAC were 7.0 kg heavier than carcasses from steers that received NORAC (394 and 387 kg, for RAC and NORAC respectively; $P < 0.01$; Table 3). Furthermore, carcasses of steers supplemented RAC also had 0.9 cm^2

increased LM area compared to carcasses from steers that received NORAC (82.3 and 80.0 cm^2 for RAC and NORAC, respectively; $P = 0.01$; Table 3). There were no effects of RAC supplementation on 12^{th} rib fat thickness, calculated yield grade, marbling score, or the percentage of abscessed livers ($P \geq 0.42$; Table 3).

Previous authors have reported RAC supplementation increases HCW, LM area and dressing percentage of feedlot cattle at time of harvest, with little to no impact on 12^{th} rib fat thickness, or marbling characteristics (Gruber et al., 2007; Quinn et al., 2008; and Boler et al., 2012). These data in the present study would agree with the conclusions previously made. Ractopamine hydrochloride supplemented at 200 or 300 mg/ steer daily dosage rates to steers during the last 28 days of feedlot finishing increased HCW 13.2 and 14.9 kg, increase LM area (83.91 and 84.04 for 200 and 300 mg/ steer daily; respectively) compared to the controls (80.04), and reported no differences in marbling scores, 12^{th} rib fat thickness, liver abscesses, calculated USDA yield grade, or quality grade distribution between the controls and supplementing ractopamine hydrochloride at either 200 or 300 mg/ steer daily (Boler et al., 2012). Furthermore, Bittner et al. (2014) reported supplementing ractopamine hydrochloride at 300 mg/ steer daily increased HCW 4.84 and 7.33 kg, compared to controls for the last 28 and 42 days, respectively. In the present study supplementation of RAC increased HCW 7 kg, and increased LM area 0.9 cm^2 with no differences in 12^{th} rib fat thickness, calculated yield grade, marbling score, or the percentage of abscess livers.

In a Reuter et al. (2007), supplemented OmniGen – AF and Sucram C in the receiving diets had no effect on HCW, 12^{th} rib fat thickness, LM area, USDA Yield

Grade, or KPH %. However, the inclusion of Sucram / OmniGen – AF combination decreased marbling score (389.4 and 370.7 with 300 = slight, for control and Sucram / OmniGen – AF; respectively) with a trend for the combination to decrease the percentage of heifers that graded USDA Choice (38.5 and 26.1%, for control and Sucram / OmniGen – AF; respectively). The authors were unaware of any mechanism that would cause the Sucram / OmniGen – AF combination to reduce marbling scores, but noted that reduced in marbling scores were reported by McMeniman et al. (2006) when Sucram was supplemented during the feedlot receiving period. Similarly in the current experiment, there was no effect of due to OmniGen – AF supplementation on HCW, 12^{th} rib fat thickness, LM area or calculated yield grade. Contrary to the study by Reuter et al. (2007) however, these data suggested no effect of OmniGen – AF supplementation on marbling score as well.

Ultrasound Data

There was no Omnigen – AF by RAC interaction observed for any of the initial, final, or ultrasound time point differences for all of the variables measured ($P \geq 0.22$; Table 4). Similarly, there was no effect of supplementing either Omnigen – AF, RAC, or their interaction during the initial ultrasound period 58 days prior to harvest for RUMP, RIB, LM area, or IMF ($P > 0.11$; Table 4). Analysis of the final ultrasound time point also indicates no effect of Omnigen – AF or RAC on RUMP ($P = 0.12$ and 0.61, respectively; Table 4).

Furthermore, there was no effect of Omnigen – AF supplementation on LM area or IMF during the final ultrasound time point ($P = 0.48$ and 0.73, respectively; Table 4).

However, RIB tended to increase among steers receiving supplementation of Omnigen – AF or RAC during the final ultrasound time point (P = 0.06 and 0.06, respectively; Table 4). Steers supplemented RAC tended to have increased RIB during the final ultrasound measurement compared to steers that were not supplemented ractopamine hydrochloride (1.54 and 1.47 cm for RAC and NO RAC, respectively; P = 0.06; Table 4). A similar tendency (P = 0.06) of an increase in RIB was also observed in cattle supplemented with Omnigen – AF during the final ultrasound period (1.41, 1.56, and 1.51 cm for 0, 28, and 56 days Omnigen- AF supplementation, respectively; Table 4).Tendencies for an effect due to supplementation of RAC for LM area and IMF during the final ultrasound were also observed (P = 0.08 and 0.10, respectively; Table 4). Supplementing RAC tended to increase LM area of steers during the final ultrasound period 1.5 cm^2 compared to NO RAC steers (90.4 and 88.9 cm^2 for RAC and NO RAC, respectively; P = 0.08; Table 4). However, a tendency for supplementation of RAC decrease IMF in steers compared to steers receiving the NO RAC treatment was observed (4.25 and 4.42 for RAC and NO RAC, respectively; P = 0.10; Table 4).

Finally, when looking at the differences in the variables (RUMP, RIB, LM area, and IMF) collected via ultrasound between the two ultrasound points, no differences were observed for RUMP, RIB, and IMF in the current study due to Omnigen – AF supplementation (P = 0.38, 0.57, and 0.92, respectively; Table 4). There was a tendency (P = 0.07) for supplementation of Omnigen – AF to increase the rate of LM area growth of steers (5.6, 4.3, and 6.6 cm^2 for 0, 28, and 56 d of Omnigen – AF supplementation, respectively; Table 4). When analyzing the effects of RAC supplementation though, there

were significant effects on LM area and IMF change ($P < 0.01$ and 0.02, respectively), but no effects on RUMP ($P = 0.87$), and only a tendency for an effect on RIB to increase ($P = 0.09$) due to RAC supplementation. Steers supplemented with RAC experienced a 2.1 cm^2 increase in steer's LM area ($P = <0.01$) between the two ultrasound time points compared to steers receiving NO RAC (6.6 and 4.6 cm^2 for RAC and NO RAC, respectively; Table 4). However, the supplementation of RAC decreased the amount of change observed in IMF compared to NO RAC steers (0.26 and 0.48 for RAC and NO RAC, respectively; Table 4). There was also a tendency ($P = 0.09$) for supplementation of RAC to increase the observed change in RIB in comparison to NO RAC steers (0.37 and 0.33 for RAC and NO RAC, respectively; Table 4).

The use of ultrasound technology provides an accurate measure of external fat thickness and longissimus muscle area (Brethour, 1992; Perkins et al., 1992; Herring et al., 1994). However, correlation coefficients between live animal ultrasound measurements and carcass measurements of fat thickness and LM area range from 0.42 to 0.92 and from 0.47 to 0.86, respectively (Houghton, 1988). Brethour (1992) evaluated the repeatability and accuracy of measuring cattle backfat through the use of ultrasound. The authors noted that measurements collected a day apart were highly correlated to one another (0.975), indicating the use of ultrasound technology to measure backfat has a high degree of repeatability. Strong correlations (0.90 and 0.92) between ultrasound backfat measures and carcass backfat measures in two separate experiments, with the average absolute differences between these measurements being 1.57 and 1.19 mm; respectively, were also reported (Brethour, 1992). In the present study, the average

absolute difference between the 56-day ultrasound measurements and the observed carcass 12-th rib fat thickness was 0.96 mm, thus indicating greater accuracy of ultrasound predicting true 12-th rib fat thickness compared with Brethour (1992). The correlation between the 56-day ultrasound measurements and true carcass measurements in the current study was 0.70 ($P < 0.01$; Figure 1). Brethour (1992) noted that the inconsistencies between measurements were greater for cattle having increased fat thickness (>10 mm) with an average absolute difference of 1.89 mm (Brethour, 1992). The observed increase in the measurement differences by Brethour (1992) was also reported by Smith et al (1989). However, in the present experiment the absolute average differences between these measurements for 89.79% of the steers having >10 mm carcass 12-th rib fat thickness measurements, the difference was less at only 0.70 mm. When analyzing the 36.94% and 3.30% of the steers in the current study that had carcass 12-th rib fat thickness measurements >15 and >20 mm, the average absolute differences decrease to only -0.09 mm before increasing to -1.36 mm, respectively. The discrepancy in the absolute differences is indicative of those analyzing ultrasound images to have the tendency to underestimate measurements for those individuals on the upper extreme of the population, while also overestimating measurements for individuals on the lower extreme of the population.

However, in contrast to the reported accuracy and repeatability of ultrasound technology for the prediction of cattle backfat and longissimus muscle area (Brethour, 1992; Perkins et al., 1992; Herring et al., 1994), Hassen et al. (1999) suggested a lower precision for the prediction of the percentage of intramuscular fat through the use of

ultrasound technology due to a relatively low repeatability among measurements. Furthermore, the authors noted that within an individual animal, 70% of the variation in was due to image variance, but suggested that the capture of multiple images per animal to increase the precision of the estimates (Hassen et al., 1999). The correlation ($r = 0.59$; $P < 0.01$; Figure 3) between the 56 d ultrasound IMF measurements to the observed carcass marbling scores in the present study.

The correlations determined between ultrasound measurement and observed carcass measurements allow the authors to feel confident in their accuracy of the use of ultrasound imaging for the prediction of change in body composition over the final 56 d of the feedlot finishing phase.

CONCLUSION

There was no Omnigen – AF by RAC interaction observed for any of the measured steer feedlot performance, carcass characteristics or change in body composition ultrasound data observed in the present study. RAC supplementation increased steer ADG, resulting in an increased FBW, HCW, and an improved G:F along with increasing LM area of carcasses. Supplementation of ractopamine hydrochloride increased the rate of accretion in steer LM area, but decreased the accretion of intramuscular fat percentage. Furthermore, these data would suggest that there is no main effect or interaction with ractopamine hydrochloride supplementation on steer feedlot

performance or carcass characteristics due to Omnigen – AF supplementation during the final 56 d of feedlot finishing.

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Table 1. Diet Composition – DM basis

	d 1 – 3	d 4-7	d 8 – 14	d 15 – 21	d 22+
Ingredient	**Step 1**	**Step 2**	**Step 3**	**Step 4**	**Finisher**
Alfalfa Hay	27.5	20.0	12.5	5.0	0.0
Corn Silage	30.0	25.0	20.0	15.0	15.0
WDGS[1]	25.0	25.0	25.0	25.0	25.0
DRC[2]	11.5	24.0	36.5	49.0	54.0
Supplement[3]	6.0	6.0	6.0	6.0	6.0

[1]Wet distillers grains plus solubles

[2]Dry rolled corn

[3]Liquid supplement; supplement provided via micomachine (Model 271 Weigh and Gain Generation 7; Animal Health International, Greely, CO) to provide 360 mg / hd / daily Rumensin® (Elanco Animal Health; DM basis) and 90 mg/ steer daily of Tylan (Elanco Animal Health). OmniGen – AF supplementation (4 g / 45.5 kg BW) was administered through topdressing the delivered finishing diet beginning 56 or 28 d prior to the targeted marketing date during the remainder of the finishing period. The topdress consisted of 50 g OmniGen – AF and 100g fine ground corn carrier (DM basis) fed to achieve 4 g OmniGen – AF / 45.5 kg steer BW

Table 2. Effects of supplementing Omnigen – AF last 0, 28, or 56 days with or without supplemented ractopamine hydrochloride the last 28 days of feedlot finishing period in crossbred beef steers on feedlot performance measures.

	NO RAC[1]			RAC				*P*-value[3]		
	0[2]	28	56	0	28	56	SEM	Omnigen	Rac	Omni x Rac
Initial BW, kg	309	310	314	314	309	308	21.01	0.90	0.89	0.53
Interim BW, kg	544	548	539	533	541	538	15.4	0.18	0.04	0.42
Final BW, kg[4]	614	613	617	625	624	626	5.6	0.82	<0.01	0.97
ADG, kg	1.75	1.75	1.76	1.81	1.80	1.81	0.06	0.89	0.02	0.99
DMI, kg/d	10.5	10.3	10.5	10.3	10.4	10.4	0.20	0.80	0.69	0.67
G:F	0.170	0.174	0.170	0.175	0.176	0.176	<0.01	0.62	0.05	0.72

[1]Steers either did not receive a beta- agonist (NO RAC) or were supplemented with ractopamine hydrochloride at 300 mg/ hd / day (RAC).
[2]Steers received Omnigen – AF® supplementation for the last 0, 28, or 56 days of the finishing period.
[3]Omnigen = main effect due to Omnigen – AF supplementation the last 0, 28, or 56 days of the finishing period; Rac = main effect due to ractopamine hydrochloride supplementation the last 0 or 28 days of the finishing period; Omni x Rac = the interaction between Omnigen – AF supplementation and ractopamine hydrochloride supplementation.
[4]Carcass adjusted final BW, used in calculation of ADG and G:F, was calculated from HCW using a common dressing percentage of 63% to minimize errors associated with gastrointestinal tract fill.

Table 3. Effects of supplementing Omnigen – AF last 0, 28, or 56 days with or without supplemented ractopamine hydrochloride the last 28 days of feedlot finishing period in crossbred beef steers on carcass characteristics.

	NO RAC[1]			RAC				*P*-value[3]		
	0[2]	28	56	0	28	56	SEM	Omnigen	Rac	Omni x Rac
HCW, kg	387	386	389	394	393	394	3.5	0.83	<0.01	0.97
LM area, cm^2	79.5	79.8	80.8	83.1	80.8	82.8	2.1	0.35	0.01	0.52
12^{th} rib fat, cm	1.35	1.43	1.37	1.32	1.48	1.45	0.07	0.10	0.42	0.55
Yield grade[4]	3.64	3.70	3.60	3.49	3.75	3.62	0.14	0.19	0.69	0.46
Marbling score[5]	454	460	447	444	455	466	12.7	0.76	0.90	0.44
Abscessed livers, %	0.07	0.04	0.04	0.08	0.07	0.11	0.31	0.80	0.18	0.62

[1]Steers either did not receive a beta- agonist (NO RAC) or were supplemented with ractopamine hydrochloride at 300 mg/ hd / day (RAC).
[2]Steers received Omnigen – AF® supplementation for the last 0, 28, or 56 days of the finishing period.
[3]Omnigen = main effect due to Omnigen – AF supplementation the last 0, 28, or 56 days of the finishing period; Rac = main effect due to ractopamine hydrochloride supplementation the last 0 or 28 days of the finishing period; Omni x Rac = the interaction between Omnigen – AF supplementation and ractopamine hydrochloride supplementation.
[4]Yield grade = 2.50 + (6.35 x fat thickness, cm) – (2.06 x LM area, cm^2) + (0.2 x KPH, %) + (0.0017 x HCW, kg).
[5]Marbling score of 400 = $small^{00}$.

Table 4. Effects of supplementing Omnigen – AF last 0, 28, or 56 days with or without supplemented ractopamine hydrochloride the last 28 days of feedlot finishing period in crossbred beef steers on change in body composition the last 56 days of feedlot finishing.

	NO RAC[1]			RAC				*P*-value[3]		
	0[2]	28	56	0	28	56	SEM	Omnigen	Rac	Omni x Rac
Initial ultrasound										
Rump fat, cm	1.02	1.09	1.07	1.03	1.07	1.16	0.05	0.12	0.47	0.44
Rib fat, cm	1.09	1.20	1.15	1.14	1.20	1.20	0.07	0.12	0.38	0.78
LM area, cm	84.3	85.1	84.1	85.1	84.1	83.1	2.8	0.46	0.62	0.70
Intramuscular fat, %[4]	4.00	4.00	3.90	3.87	4.12	4.05	0.15	0.65	0.64	0.52
Final ultrasound										
Rump fat, cm	1.28	1.40	1.36	1.30	1.37	1.43	0.05	0.12	0.61	0.62
Rib fat, cm	1.41	1.51	1.48	1.47	1.60	1.54	0.06	0.06	0.06	0.88
LM area, cm	89.4	87.9	89.2	90.7	89.9	90.9	2.2	0.48	0.08	0.94
Intramuscular fat, %[4]	4.45	4.43	4.38	4.12	4.33	4.31	0.15	0.73	0.10	0.50
Ultrasound differences[5]										
Rump fat, cm	0.28	0.32	0.29	0.28	0.31	0.28	0.03	0.38	0.87	0.95
Rib fat, cm	0.33	0.31	0.33	0.34	0.41	0.35	0.03	0.57	0.09	0.22
LM area, cm	5.1	3.0	5.3	5.8	5.8	8.1	1.2	0.07	<0.01	0.43
Intramuscular fat, %[4]	0.47	0.45	0.50	0.26	0.23	0.28	0.16	0.92	0.02	1.00

[1]Steers either did not receive a beta- agonist (NO RAC) or were supplemented with ractopamine hydrochloride at 300 mg/ hd / day (RAC).
[2]Steers received Omnigen – AF® supplementation for the last 0, 28, or 56 days of the finishing period.
[3]Omnigen = main effect due to Omnigen – AF supplementation the last 0, 28, or 56 days of the finishing period; Rac = main effect due to ractopamine hydrochloride supplementation the last 0 or 28 days of the finishing period; Omni x Rac = the interaction between Omnigen – AF supplementation and ractopamine hydrochloride supplementation.
[4]Percentage of intramuscular fat (IMF) were 2.3 – 3.9 = Select, 4.0 – 5.7 = Choice $^{-}$, 5.8 – 7.6 = Choice °, 7.7 – 9.7 = Choice $^{+}$, and 9.9 – 12.3 = Prime.
[5]Ultrasound difference calculated by subtracting final ultrasound measurements from initial ultrasound measurements.

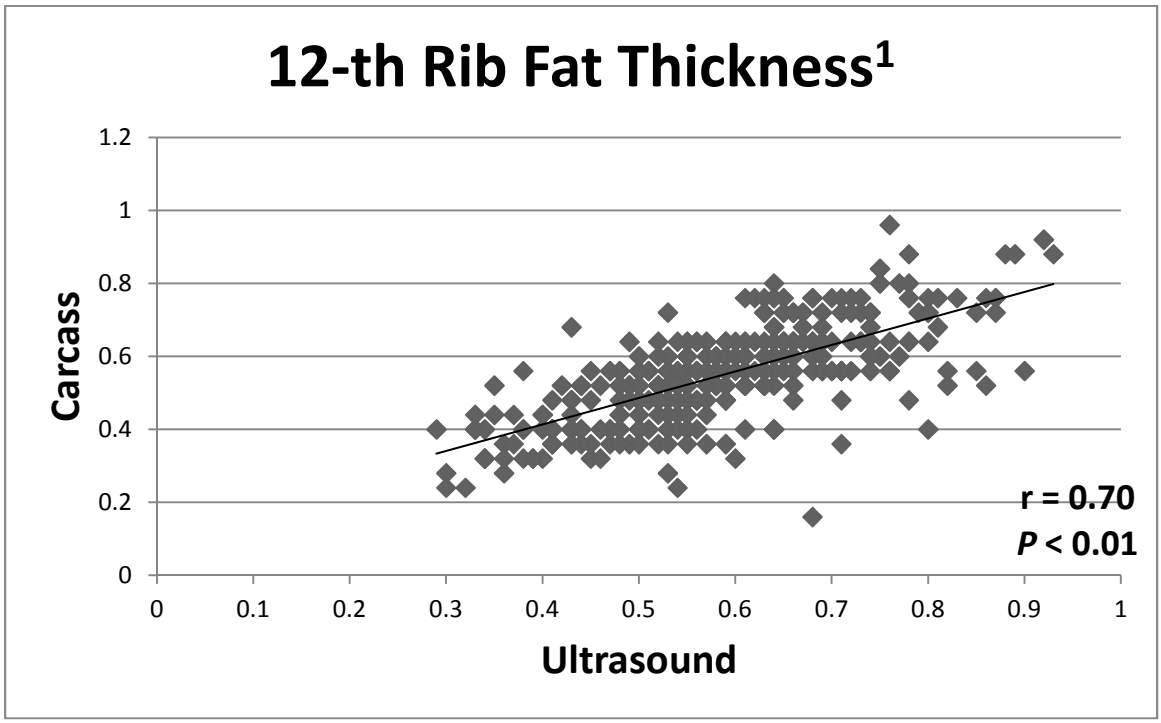

Figure 1. Correlation between d 56 ultrasound 12-th rib fat thickness measurement to observed carcass 12-th rib fat thickness measurement.

[1]Each data point represents relationship between 12th rib fat thickness measurement collected 1 d prior to harvest with the observed 12th rib fat thickness measurement of the carcass for each individual animal (n = 333).

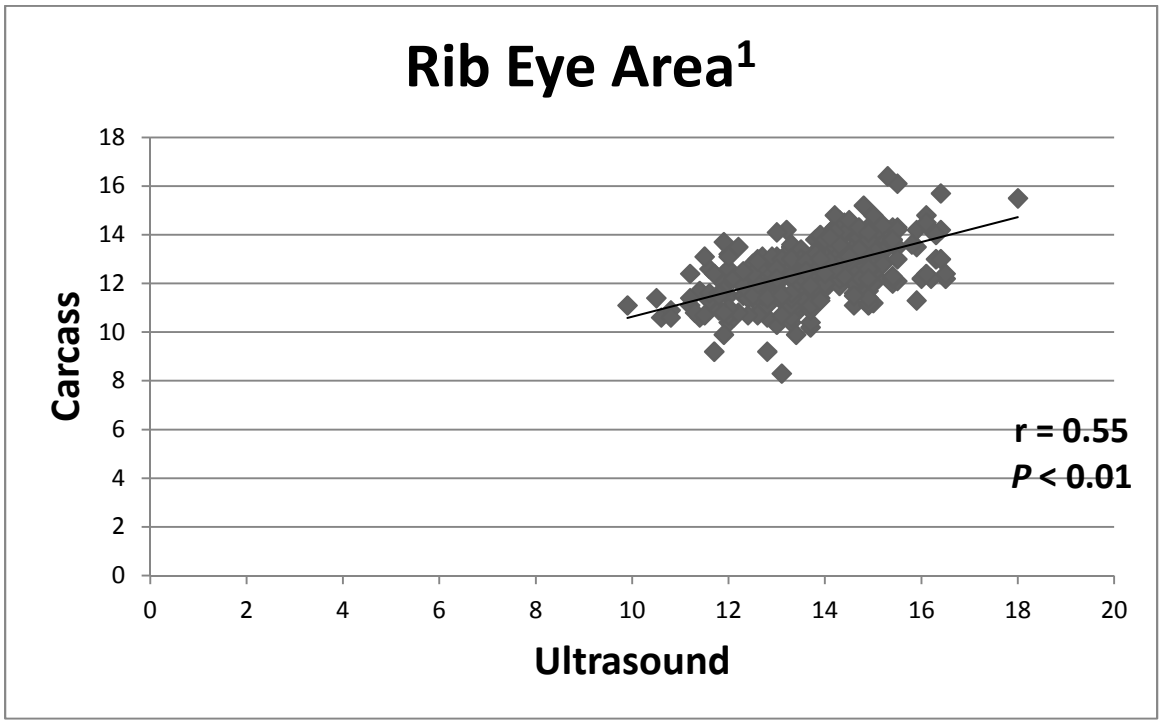

Figure 2. Correlation between d 56 ultrasound longissimus muscle area measurement to observed carcass longissimus muscle area measurement.
[1]Each data point represents relationship between longissimuss muscle area estimate collected 1 d prior to harvest with the observed longissimuss muscle area measurement of the carcass for each individual animal (n = 333).

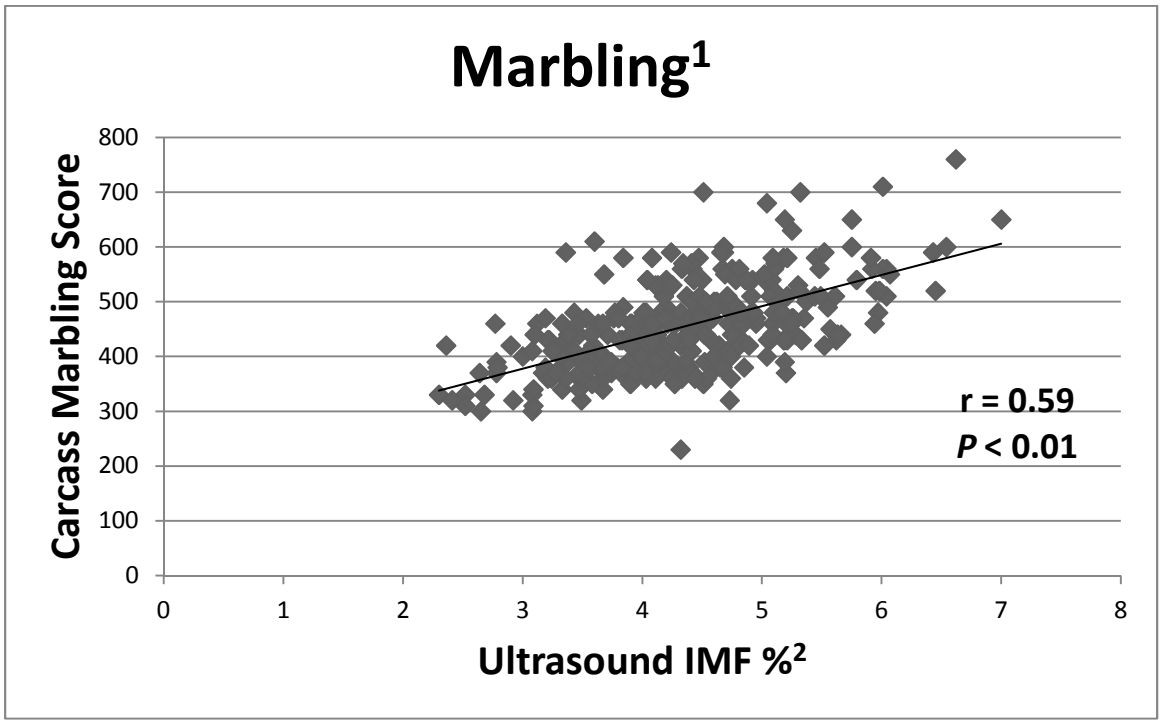

Figure 3. Correlation between d 56 ultrasound intramuscular fat percentage measurement to observed carcass marbling score.

[1]Each data point represents relationship between ultrasound estimate intramuscular fat percentage collected 1 d prior to harvest with the observed carcass marbling scoret for each individual animal (n = 333).

[2]Percentage of intramuscular fat (IMF) were 2.3 – 3.9 = Select, 4.0 – 5.7 = Choice -, 5.8 – 7.6 = Choice °, 7.7 – 9.7 = Choice +, and 9.9 – 12.3 = Prime.

CHAPTER V: APPENDIX

Thiobarbituric Acid Assay.

Buege and Aust (1978), Modified by Ahn et al. (1998)

TEP Solution (1,1,3,3 – Tetraethoxypropane) (Make new weekly)

Stock solution: Dilute 99 µ TEP (97%) bring volume to 100 mL ddH_2O

Working Solution: Dilute stock solution to 1:3 (TEP solution: ddH_2O) ($1x10^{-3}$M)

TBA / TCA (2 – Thiobarbutaric acid / Trichloroacetic Acid) Stock Solution: 1L

15% TCA (w/v) and 20 mL TBA (MW 144.5) reagent in ddH_2O

Dissolve 2.88g TBA in warm ddH_2O first, then add TCA (150g) and ddH_2O to 1L

BHA (Butylated Hydroxyanisole) Stock Solution:

10g BHA dissolved in 90 mL ethanol (90%) + 5 mL ddH_2O.

Make 10% stock solution by dissolving in 90% ethanol.

Standards: In duplicate		**Moles of TEP**
Blank:	1 ml ddH_2O	
Standard 5	100µL working TEP + 1.90 mL ddH_2O	$5x10^{-5}$M
Standard 4	1 mL Std. 5 + 1 mL ddH_2O	$2.5x10^{-5}$M
Standard 3	1 mL Std. 4 + 1 mL ddH_2O	$1.25x10^{-5}$M
Standard 2	1 mL Std. 3 + 1 mL ddH_2O	$.625x10^{-5}$M
Standard 1	1 mL Std. 2 + 1 mL ddH_2O	$.3125x10^{-5}$M

Remove 1 mL of Standard 1 and discard it, leaving 1 mL behind.

Procedure

- Mix all reagents and standards before beginning
- Transfer 5g of powdered sample into a 50 mL conical tube, add 14 mL of ddH_2O and 1.0 mL of BHA (Butylated hydroxyanisole)
- Homogenize for 15 sec with a polytron
- Centrifuge for 2000xg for 5 minutes
- Transfer 1 mL of homogenate or standard to 15 mL conical tube
- Add 2 mL of TBA/TCA solution, vortex
- Incubate in 70°C water bath for 30 min to develop color
- Cool samples in a cold water bath for 10 min.
- Centrifuge tubes at 2000xg for 15 min.
- Transfer duplicate aliquots of 200µL from each tube into wells on a 96 well plate
- Read absorbance at 540nm

Calculations: mgs of malonaldehdye/ kg of tissue

K(extraction) = (S/A) x MW x (10^6E) x 100

Where S = Standard concentration ($1x10^{-8}$ moles 1,1,3,3 – tetraethoxypropane)/ 5 mL.

A = absorbance of standard — MW = MW of malonaldehdye (72.063 g/ mole)

E = sample equivalent (1) — P = Percent recovery

Final Calculation = 0.12 x concentration x $72.063x10^6$ = mgs Malonaldehdye / kg of tissue

Reagents (Sigma): TBA – T5500; TCA – T9159; TEP – T9889; BHA – B1253

Fatty Acid Determination

1. Weigh out 1.0g of pulverized muscle tissue. If extracting subcutaneous fat, weigh out 0.1g of pulverized subcutaneous fat into centrifuge tube.
2. Add 5 mL of 2:1 - chloroform:methanol (v/v) for muscle tissue or 3 mL for subcutaneous fat.
3. Vortex for 5 sec and let stand for 1 hour at room temp
4. Filter homogenate through Whatman #2 filter paper into 13x150 mm screw cap tube bringing the final volume with 2:1 - chloroform:methanol to 10 mL for muscle lipid and 5 mL for subcutaneous fat extract. If stopping at this point, purge test tube with nitrogen, cap tube, and store at -80°C.
5. Add 2 mL of a 0.74% KCl solution for muscle lipid extract or 1 mL for subcutaneous fat tissue extract and vortex for 5 sec. If stopping at this point, purge test tube with nitrogen, cap tube, and store at -80°C.
6. Centrifuge samples at 1000 x g for 5 min. Following centrifugation, aspirate off the aqueous phase (top layer). If stopping at this point, purge test tube with nitrogen, cap tube, and store at -80°C.
7. Evaporate to dryness under nitrogen at 60°C.
8. Add 0.5 mL of NaOH in methanol. Vortex for 5 sec. Heat for 5 min at 100°C.
9. Add 0.5 mL of boron trifluoride in 14% methanol. Vortex for 5 sec. Heat for 5 min at 100°C.
10. Add 1 mL of a saturated salt solution and 1 mL of hexane. Vortex for 5 sec.
11. Centrifuge samples at 1000 x g for 5 min. Following centrifugation, remove hexane layer (top layer) **making sure not to disrupt the aqueous phase** (lower layer) and place in Gas Chromatology (GC) vial. Purge GC vial with nitrogen, cap and crimp cap, and store at -80°C until sample is ready to be read on the GC.

GC Settings

Column - Chrompack CP-Sil 88 (0**.**25 mm x 100 m)
Injector Temp – 270°C
Detector Temp – 300°C
Head Pressure – 40 psi
Flow Rate – 1.0 mL/min
Temperature Program – Start at 140°C and hold for 10 min. Following 10 min, raise temperature 2°C/ min until temperature reaches 220°C. At 200°C, hold for 20 min.

Proximate Analysis

University of Nebraska – Lincoln
Meat Science and Muscle Biology Research Lab
A.O.A.C. Methods – Serial Sample Analysis

Sample Preparation

Section a portion of meat into small pieces Place the pieces in a plastic bag (doubled if a thin bag), mark bag with identification number with a Sharpie or include identification tag in bag and place in ultralow freezer until completely frozen or, if in a hurry you can freeze the sample in liquid nitrogen. To powder the sample, first blend a small amount of liquid nitrogen to chill the blender cup. Blend a small amount of sample, then add additional sample to the blender cup. When the sample has been ground to a fine powder transfer it back into the double plastic bag and secure with a rubber band. Store the sample in the ultralow freezer immediately (*Remember to keep the sample frozen at all times and to keep the blender cups cold by placing upside down in liquid nitrogen*).

Moisture and Ash by LECO

(This portion of the proximate analysis will be done on a Thermogravimetric Analyzer (TGA- 701) Leco Corp., St. Joseph MO.)

1. Powdered samples are removed from ultralow freezer.
2. Samples are stored in a small stryo-foam cooler containing liquid nitrogen to keep from thawing while loading subsamples into the TGA-701. Samples are kept in their original plastic bags so they do not come in direct contact with the liquid nitrogen.
3. Sample identification numbers are entered into the computer.
4. The method of operation is selected (User defined).

Name	Covers	RampRate	RampTime	StartTemp	EndTemp
Moisture	Off	6 d/ m	:17min	25C	130C
Ash	Off	20 d/m	:30 min	130C	600C

Name	Atmosphere	FlowRate	HoldTime	Const. Wt.	Const.Wt.Time
Moisture	N	High	00 min	0.05%	09 min
Ash	O	High	00 min	0.05%	09 min

General Setting

Crucible Density		3.00
Cover Density		3.00
Sample Density	1.00	

Equations

Initial Wt.	W[Initial]
Moisture	((W[Initial] – W[Moisture])/W[Initial])*100
Ash	(W[Ash]/[Initial]) * 100
Ash Dry Basis	E[Ash] * (100/(100-E[Moisture]))

Procedure continued…

5. Select “Analysis” and click on “collect”.
6. Select furnace to be used.
7. Load empty crucibles into selected furnace.
8. TGA-701 will weigh all crucibles to obtain a tare weight.
9. After tare is obtained the machine will call to load each sample (1g).
10. Return samples to ultra-low freezer.
11. After all samples are loaded the machine will automatically start.
12. When analysis is finished click the “save” icon on toolbar and print a hard copy of results.
13. Remove crucibles after they have cooled down for 30 minutes. Wash them in soapy water and allow to dry in drying oven for at least 1 ½ hours.
14. Remove dry crucibles and transfer to desiccator for future use.
15. Before doing another run the machine must cool down to 25°C.

Fat Extraction

Soxhlet Method

1. Check ground glass connections. They should be wiped clean with a dry paper towel and given a thin coating of stopcock grease.
2. Each boiling flask must contain boiling stones. This helps prevent violent boiling of the solvent could be dangerous.
3. Load samples into soxhlet tubes, arranging them so that no samples are above the level of the top bend in the narrower tubing on the outside of the soxhlet. (The soxhlet will only fill with the solvent up to this point before cycling back down into the boiling flask). In general, the large soxhlets will hold about 20 two- gram samples.
4. Fill the large (500 mL boiling flasks with 400 mL of solvent. DO THIS UNDER THE FUME HOOD!
5. Fit the soxhlet onto the boiling flask. Very carefully fit it onto the condenser. Make sure all ground glass connections are snug and each boiling flask is resting on the heating element. The ceramic fiber sheet would be covering the bare metal surfaces of the burners completely.
6. Turn on the water supply to the condensers. Check later to make sure condensers are cool enough – if not, increase water flow.
7. Turn heating element control dials to between three and four. Each burner has its own dial. NEVER TURN THE BURNER BEYOND FIVE. Double check fittings, boiling stones, etc.
8. Fat extraction will take from 24 to 72 hours depending on the sample. (Beef -48 hours, Bacon - 72 hours). Check extractions twice daily to see that everything is alright while they are running.
9. When done turn off the burners and let solvent cool completely before removing samples.
10. After it has cooled down, slowly uncouple the flask and soxhlet tube from the condenser. Air dry samples in the fume hood for two hours to get rid of the remaining ether in the samples. Pour ether back slowly into an approved container for reuse or discarding.
11. Place samples in drying oven (105°C) for about 4 hours or overnight before weighing back

Calculation: ((Original weight including filter paper and paper clip) – (fat extracted sample weight) * 100)) - % Moisture = % Fat

TABLE 1. *P* – values from the effects of feeding distillers grains throughout a yearling beef production system on steak discoloration percentage.

Item	Age	Retail	Winter	Summer	Finishing	W x S	W x F	S x F	W x S x F
	<0.01	<0.01	<0.01	0.01	<0.01	0.61	0.39	0.01	0.85
Age Interaction	-	<0.01	0.42	<0.01	0.17	0.47	0.20	0.21	0.83
Retail Interaction	<0.01	-	0.06	0.47	0.02	0.98	0.78	0.27	1.00
Age x Retail Interaction	-	-	0.14	0.31	<0.01	0.84	0.82	0.52	1.00

TABLE 2. Effects of feeding distillers grains throughout a yearling beef production system on steak discoloration.

	HW				LW				
	SS		NS		SS		NS		
Item	**DGF**	**CGF**	**DGF**	**CGF**	**DGF**	**CGF**	**DGF**	**CGF**	**SEM**
Discoloration Avg.	19.79	17.47	20.40	13.86	17.30	16.00	16.82	11.90	1.13
7 d Aged Avg.	6.40	3.03	8.75	3.45	2.70	2.64	3.19	1.13	1.61
Retail d 0	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	4.63
1	0.04	0.00	0.00	0.02	0.04	0.03	0.02	0.02	4.63
2	0.25	0.15	0.20	0.06	0.09	0.07	0.10	0.02	4.63
3	0.84	0.75	0.75	0.35	0.38	0.17	0.37	0.23	4.63
4	1.95	1.50	1.35	0.86	0.87	0.60	0.82	0.30	4.63
5	3.80	3.00	3.67	2.35	1.77	1.37	1.43	0.73	4.63
6	15.65	5.32	21.52	5.29	5.51	6.27	6.28	2.05	4.63
7	28.71	13.50	42.52	18.65	12.93	12.62	16.50	5.68	4.63
21 d Aged Avg.	33.18	31.91	32.04	24.28	31.90	29.35	30.46	22.68	1.61
Retail d 0	1.31	0.32	1.28	0.18	1.13	0.73	0.23	0.27	4.63
1	1.33	0.48	0.87	0.38	1.29	0.98	0.20	0.35	4.63
2	1.40	0.83	1.50	0.51	1.96	0.97	0.47	0.40	4.63
3	2.98	1.72	4.25	1.37	9.71	2.66	3.95	1.47	4.63
4	26.09	18.03	27.77	8.52	22.40	14.22	20.28	4.42	4.63
5	55.62	51.48	52.07	32.23	48.11	43.10	53.42	24.82	4.63
6	82.18	86.57	77.83	64.52	77.96	77.75	74.97	62.00	4.63
7	94.56	95.82	90.78	86.52	92.60	94.42	90.15	87.72	4.63

TABLE 3. *P* – values from the effects of feeding distillers grains throughout a yearling beef production system on steak oxidative rancidity.

Item	Age	Retail	Winter	Summer	Finishing	W x S	W x F	S x F	W x S x F
	<0.01	<0.01	0.88	0.85	0.69	0.99	0.91	0.21	0.37
Age Interaction	-	<0.01	0.63	0.66	0.76	0.30	0.27	0.59	0.81
Retail Interaction	<0.01	-	0.79	0.58	0.68	0.58	0.69	0.16	0.17
Age x Retail Interaction	-	-	0.50	0.47	0.80	0.80	0.26	0.35	0.64

TABLE 4. Effects of feeding distillers grains throughout a yearling beef production system on steak oxidative rancidity.

	HW				LW				
	SS		NS		SS		NS		
Item	**DGF**	**CGF**	**DGF**	**CGF**	**DGF**	**CGF**	**DGF**	**CGF**	**SEM**
TBA Avg.[1]	3.94	4.61	4.89	3.82	4.20	4.23	4.42	4.16	0.59
7 d Aged	3.43	3.21	4.30	2.97	3.75	3.98	3.26	3.44	0.83
Retail d 0	1.29	0.61	1.86	1.04	2.68	1.40	1.05	1.66	0.96
4	3.14	3.02	4.25	2.71	3.08	3.98	2.82	2.74	0.96
7	5.85	6.00	6.80	5.16	5.48	6.57	5.90	5.93	0.96
21 d Aged	4.46	6.00	5.48	4.66	4.64	4.48	5.58	4.88	0.83
Retail d 0	1.65	3.26	3.05	1.02	2.09	1.61	1.52	1.98	0.96
4	4.72	6.15	6.06	4.90	4.59	4.78	6.37	5.09	0.96
7	6.70	8.61	7.32	8.06	7.26	7.04	8.87	7.57	0.96

TABLE 5. *P* – values from the effects of feeding distillers grains throughout a yearling beef production system on steak tenderness.

Item	Age	Retail	Winter	Summer	Finishing	W x S	W x F	S x F	W x S x F
	<0.01	<0.01	0.17	0.02	0.17	0.27	0.39	0.63	0.05
Age Interaction	-	0.39	0.37	0.37	0.74	0.60	0.39	0.26	0.92
Retail Interaction	0.39	-	0.64	0.43	0.73	0.90	0.97	0.09	0.57
Age x Retail Interaction	-	-	0.16	0.77	0.92	0.41	0.31	0.74	0.20

TABLE 6. Effects of feeding distillers grains throughout a yearling beef production system on steak tenderness.

	HW				LW				
	SS		NS		SS		NS		
Item	**DGF**	**CGF**	**DGF**	**CGF**	**DGF**	**CGF**	**DGF**	**CGF**	**SEM**
WBSF, kg	3.23	3.35	3.24	3.18	3.50	3.44	3.09	3.37	0.09
7 d Aged	3.41	3.61	3.50	3.37	3.65	3.64	3.29	3.42	0.13
Retail d 0	3.57	3.73	3.61	363	4.01	3.76	3.46	3.68	0.17
7	3.25	3.50	3.30	3.10	3.29	3.53	3.09	3.15	0.17
21 d Aged	3.06	3.08	3.03	3.00	3.26	3.25	2.90	3.33	0.13
Retail d 0	3.40	3.15	3.18	3.27	3.26	3.32	3.05	3.50	0.17
7	2.72	3.01	2.88	2.73	3.26	3.17	2.75	3.17	0.17

TABLE 7. *P* – values from the effects s of feeding distillers grains throughout a yearling beef production system on steak fatty acid profile (fat percentage basis) and total fat percentage.

Item	Winter	Summer	Finishing	W x S	W x F	S x F	W x S x F
Fatty Acid Profile							
14:0	0.43	0.27	0.01	0.83	0.89	0.89	0.90
14:1	0.74	0.10	0.54	0.91	0.99	0.78	0.17
15:0	0.71	0.88	0.08	0.28	0.51	0.64	0.26
15:1	0.03	0.48	0.35	0.51	0.29	0.93	0.88
16:0	0.38	0.93	0.97	0.42	0.95	0.19	0.17
16:1	0.02	0.31	<0.01	0.29	0.60	0.43	0.81
17:0	0.86	0.17	<0.01	0.14	0.10	0.96	0.33
17:1	0.38	0.60	<0.01	0.86	0.07	0.15	0.74
18:0	0.04	0.50	0.09	0.48	0.79	0.06	0.26
18:1*t*	0.25	0.60	<0.01	0.23	0.96	0.55	0.75
18:1	0.51	0.71	<0.01	0.30	0.49	0.15	0.05
18:1*v*	0.86	0.94	<0.01	0.80	0.27	0.32	0.43
19:0	0.66	0.72	0.09	0.25	0.58	0.36	-
18:2	0.97	0.96	<0.01	0.46	0.48	0.90	0.94
20:0	0.09	0.82	0.85	0.63	0.49	0.79	0.51
20:3	0.60	0.64	0.83	1.00	0.57	0.24	0.63
20:4	0.35	0.47	0.85	0.10	0.23	0.69	0.46
Unknown	0.55	0.54	<0.01	<0.01	0.65	0.05	0.20
PUFA	0.83	0.80	<0.01	0.33	0.42	0.80	0.97
MUFA	0.21	0.55	<0.01	0.53	0.43	0.08	0.06
SFA	0.17	0.60	0.41	0.49	0.62	0.07	0.08
PUFA:SFA	0.79	0.65	<0.01	0.33	0.50	0.83	0.58
Fat%	0.18	0.71	0.58	0.23	<0.01	0.21	0.78

TABLE 8. Effects of feeding distillers grains throughout a yearling beef production system on steak fatty acid profile (fat percentage basis) and total fat percentage.

	HW				LW				
	SS		NS		SS		NS		
Item	**DGF**	**CGF**	**DGF**	**CGF**	**DGF**	**CGF**	**DGF**	**CGF**	**SEM**
Fatty Acid Profile									
14:0	2.65	2.44	2.56	2.40	2.60	2.40	2.51	2.30	0.11
14:1	0.64	0.61	0.54	0.61	0.59	0.64	0.67	0.56	0.05
15:0	0.48	0.53	0.50	0.57	0.51	0.57	0.52	0.51	0.04
15:1	0.60	0.58	0.59	0.59	0.61	0.69	0.67	0.75	0.06
16:0	24.40	24.36	24.65	24.67	23.81	24.90	24.52	23.51	0.57
16:1	2.96	3.30	2.74	3.17	2.73	2.94	2.65	3.03	0.12
17:0	1.40	1.72	1.49	1.89	1.50	1.75	1.54	1.70	0.07
17:1	0.98	1.30	0.93	1.37	0.99	1.21	0.98	1.27	0.05
18:0	14.50	14.00	15.34	14.26	15.05	15.68	16.24	14.47	0.59
18:1*t*	3.40	1.23	3.50	1.47	3.51	1.15	2.84	0.95	0.36
18:1	35.95	39.84	35.41	38.59	36.58	37.06	34.83	39.66	0.93
18:1*v*	1.69	1.89	1.69	1.91	1.81	1.81	1.70	1.89	0.07
19:0	0.46	-	0.50	0.38	0.46	0.30	0.38	0.36	0.11
18:2	3.90	2.89	3.83	2.76	3.70	2.86	3.92	2.97	0.21
20:0	4.50	4.14	4.24	4.20	4.45	5.17	5.11	5.10	0.59
20:3	0.26	0.28	0.27	0.21	0.23	0.37	0.30	0.24	0.09
20:4	0.77	0.71	0.65	0.62	0.65	0.77	0.75	0.76	0.07
Unknown	0.94	0.69	1.07	0.93	1.28	0.72	0.70	0.71	0.15
PUFA	4.70	3.67	4.52	3.39	4.42	3.66	4.59	3.76	0.26
MUFA	46.26	48.65	45.46	47.69	46.82	45.34	44.21	48.02	1.05
SFA	48.11	47.11	49.04	48.02	47.95	50.43	50.56	47.57	1.11
PUFA:SFA	0.098	0.078	0.094	0.071	0.092	0.074	0.092	0.079	<0.01
Fat%	6.31	6.99	6.08	7.77	7.18	6.04	6.34	5.85	0.48

TABLE 9. *P* – values from the effects of feeding distillers grains throughout a yearling beef production system on fatty acid profile (mg/ 100 g muscle tissue) and fat percentage.

Item	Winter	Summer	Finishing	W x S	W x F	S x F	W x S x F
Fatty Acid Profile							
14:0	0.15	0.48	0.37	0.20	0.01	0.31	0.73
14:1	0.03	0.49	0.57	0.54	0.02	0.30	0.48
15:0	0.10	0.18	0.31	0.20	0.11	0.50	0.17
15:1	0.50	0.41	0.19	1.00	0.04	0.29	0.95
16:0	0.15	0.84	0.65	0.17	<0.01	0.47	0.49
16:1	0.02	0.51	0.01	0.45	<0.01	0.14	0.96
17:0	0.20	0.66	<0.01	0.11	<0.01	0.29	0.42
17:1	0.07	0.80	<0.01	0.28	<0.01	0.09	0.54
18:0	0.86	0.90	0.65	0.21	0.02	0.80	0.51
18:1*t*	0.36	0.28	<0.01	0.12	0.42	0.19	0.82
18:1	0.17	0.67	0.05	0.51	<0.01	0.12	0.75
18:1*v*	0.30	0.70	0.06	0.32	<0.01	0.12	0.99
19:0	0.72	0.88	<0.01	0.57	0.51	0.70	0.73
18:2	0.20	0.37	<0.01	0.62	0.02	0.27	0.86
20:0	0.44	0.98	0.60	0.75	0.26	0.89	0.48
20:4	0.80	0.11	0.20	0.29	0.13	0.87	0.26
Unknown	0.19	0.85	0.15	0.18	0.51	0.12	0.96
PUFA	0.25	0.22	<0.01	0.78	0.01	0.31	0.84
MUFA	0.13	0.62	0.21	0.40	<0.01	0.09	0.82
SFA	0.35	0.87	0.86	0.15	<0.01	0.55	0.42
PUFA:SFA	0.79	0.65	<0.01	0.33	0.50	0.83	0.58
Fat%	0.18	0.71	0.58	0.23	<0.01	0.21	0.78

TABLE 10. Effects of feeding distillers grains throughout a yearling beef production system on fatty acid profile (mg/ 100 g muscle tissue) and fat percentage.

	HW				LW				
	SS		NS		SS		NS		
Item	**DGF**	**CGF**	**DGF**	**CGF**	**DGF**	**CGF**	**DGF**	**CGF**	**SEM**
Fatty Acid Profile									
14:0	166.18	169.44	158.70	188.69	186.67	145.87	160.40	132.91	14.34
14:1	38.98	42.47	33.31	47.61	39.08	32.63	33.95	29.64	4.53
15:0	29.04	30.68	30.74	44.71	28.61	28.97	30.81	26.96	4.36
15:1	35.25	39.83	34.63	43.71	40.67	37.08	40.30	40.72	2.91
16:0	1537.03	1690.92	1516.54	1915.58	1708.67	1507.52	1569.57	1374.00	125.49
16:1	184.48	228.85	166.70	248.65	196.52	175.15	161.94	178.52	24.48
17:0	90.36	120.62	91.74	148.68	109.28	106.53	98.97	99.94	10.40
17:1	61.18	90.80	56.44	108.34	71.27	73.48	62.02	74.70	7.00
18:0	927.37	983.61	940.65	1102.75	1087.70	949.34	1030.36	845.98	85.14
18:1*t*	223.68	78.1001	212.57	107.60	255.26	71.34	177.15	50.70	27.05
18:1	2281.28	2807.44	2136.06	3019.23	2643.78	2243.07	2221.74	2356.18	208.09
18:1*v*	108.23	133.14	100.85	149.78	130.66	110.21	108.34	111.56	11.02
19:0	15.2213	0.00	14.37	3.09	13.03	3.31	10.96	1.45	4.00
18:2	242.70	199.45	226.48	207.93	256.77	170.42	234.41	166.02	14.03
20:0	261.58	284.62	255.92	302.60	293.51	298.61	303.96	273.66	30.81
20:4	45.54	48.68	37.39	45.87	43.67	45.17	44.54	42.06	2.99
Unknown	59.74	39.58	59.15	66.02	65.25	34.63	42.74	37.53	12.35
PUFA	289.85	252.61	266.12	255.49	306.10	217.31	280.72	209.71	15.92
MUFA	2936.21	3420.62	2744.65	3732.90	3382.42	2747.32	2814.88	2844.88	254.02
SFA	3026.78	3279.89	3008.66	3706.10	3427.47	3040.14	3205.04	2754.90	230.34
PUFA:SFA	0.098	0.078	0.094	0.071	0.092	0.074	0.092	0.079	<0.01
Fat%	6.31	6.99	6.08	7.77	7.18	6.04	6.34	5.85	0.48