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# STRATEGIES FOR BEEF CATTLE ADAPTATION TO FINISHING DIETS, RACTOPAMINE HYDROCHLORIDE UTILIZATION, AND MATURE SIZE GENETIC SELECTION

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by

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# STRATEGIES FOR BEEF CATTLE ADAPTATION TO FINISHING DIETS, RACTOPAMINE HYDROCHLORIDE UTILIZATION, AND MATURE SIZE GENETIC SELECTION

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A cattle finishing experiment was conducted to evaluate effects of intermittent feeding of Optaflexx compared to none or continuous feeding. Four treatments were evaluated, the negative control consisted of 63 days on the same diet without Optaflexx, wherea the positive control consisted of Optaflexx supplemented daily during the last 35 days before harvest. The 4-day intermittent treatment consisted of feeding Optaflexx for7 days, followed by 4 days of no Optaflexx, and the 7-day intermittent treatment 7 d on Optaflexx, followed by 7 days off. Regardless of the delivery pattern, feeding Optaflexx increased ADG, DMI, and live BW compared to negative control. Feeding 200 mg per steer daily of Optaflexx for a total of 35 days in either 4-day or 7-day intermittent patterns was as effective as continuous feeding.

A study was conducted to estimate genetic parameters for weights and heights of mature cows using a repeatability model from field data provided by the American Angus

Association. The results show that the heritability of both traits is large and correlations between them are positive and strong. Results suggest that either trait would response favorably to selection and changing one would lead to a correlated response in the other.

A feedlot cattle finishing experiment and two 39-day metabolism trials were conducted using a combination of modified distillers grains and wet corn gluten feed to adapt beef cattle to finishing diets. During adaptation, DMI tended to be greater for traditional adaptation with forage compared to the co-product blend during the first period, but not different in subsequent periods. Average ruminal pH was lower for the co-product blend on step 1 and 2 compared to forage in Exp. 1 with no difference observed in Exp. 2. No difference in ruminal pH was observed between treatments for step 3 and 4. Significant difference was observed for DM digestibility between treatments during step 1 with higher values for the co-product treatment. Results from the feedlot experiment were not significantly different between treatments. Results indicate that a combination of MDGS and WCGF may be a viable method to adapt beef cattle to finishing high-concentrate diets for feedlots.

**Key Words:** Acidosis, adaptation, co-products, mature size, ractopamine

# DEDICATION

I dedicate this thesis to my family and especially to my brother,

***Osmanio Dib Junior***,

whom always gives me the strength to keep moving, always has a smile on his face to remind me that life is a great gift and everybody should make the most of it. He taught me that nothing is impossible and happiness is only true if shared.

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# TABLE OF CONTENTS

**Chapter**

**I.**INTRODUCTION..……....1

**II**. REVIEW OF LITERATURE I..……..…4

Corn Production and Utilization in the USA……...4
Ethanol Industry in the USA……....5
Ethanol Co-Products for Ruminants……8
Modified Distillers Grains with Solubles……..10
Wet Corn Gluten Feed……...11
Grain Adaptation Diets to Prevent Acidosis……..12

REVIEW OF LITERATURE II…….....20
β- adrenergic agonists in Livestock……..20
Characterization of Ractopamine Hydrochloride…….20
Early Research on Ractopamine Hydrochloride Fed to Livestock……...22
Present Research on Ractopamine Hydrochloride Fed to Beef Cattle…….25
Intermittent Feeding of Ractopamine Hydrochloride……...27

REVIEW OF LITERATURE III…….....29
Genetic Parameters of Mature Size in Beef Cattle……29

LITERATURE CITED……..34

**III.** EFFECTS OF FEEDING A COMBINATION OF MODIFIED DISTILLERS GRAINS WITH SOLUBLES AND WET CORN GLUTEN FEED TO ADAPT CATTLE TO FINISHING DIETS……49

Abstract……..49

Introduction……50

Materials and Methods……...52

Results and Discussion……..59

Literature Cited……..67

Tables……70

Figures……80

**IV.** EFFECTS OF INTERMITTENT FEEDING OF RACTOPAMINE HYDROCHLORIDE ON GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF FEEDLOT STEERS.....82

Abstract……..82

Introduction……83

Materials and Methods……...85

Results and Discussion……..88

Literature Cited……..92

Tables……95

Figures……98

**V.** GENETIC PARAMETERS FOR MATURE COW WEIGHT AND HEIGHT IN AMERICAN ANGUS CATTLE……...99

Abstract..……99

Introduction……..100

Materials and Methods…….101

Results and Discussion……103

Literature Cited……106

Tables……...108

Figures……..112

# CHAPTER I

## INTRODUCTION

Human civilization have lived and learned to control domesticated animals for at least 10,000 years. Humans changed their behavior throughout the hundreds of years and wild animals with potential to be explored became tamed. Animals have provided a diverse number of products that facilitate human life quality such as wool, skin, meat, milk, eggs, among others. Animals also are used for transportation, labor and traction, companion, hunting along with other activities for necessity or recreation of human life.

Different animals were domesticated in different parts of the world at different times, and ruminants, classified in the order *Arteriodactyla* and suborder *ruminantia,* were one of them. Approximately 155 species of ruminants can be found around the globe but only about 6 of them are domesticated, cattle, sheep, goats, buffaloes, reindeer and yaks (Van Soest, 1994). Ruminants are different from all other mammals because of its digestive anatomy composed by four stomach compartments (reticulum, rumen, omasum and abomasum). Another unique characteristic is the interaction between animal, plant and microorganisms present inside the gastrointestinal tract resulting in a symbiotic relationship through gastroenteric microbial fermentation. Plants consumed by ruminants are utilized as substrates by the microorganisms and the products from fermentation and microorganisms provide energy and protein to the host animal. Animal products such as milk and meat have always been an important component of human

diets, therefore technologies to enhance production efficiency and increase economic return for producers are important.

Scientific development and creation of new technologies to supply the food requirements due to increase in human population is one of the concerns for the future. Innovations and solutions to improve agriculture production systems become necessary. Use of alternative nutrient sources, feed strategies, additives and implants, genetic selection programs, among other options may be important to reach objectives of producers, packers, consumers, etc.

Genetic programs to improve desirable characteristics with economic merits have been successful in livestock production so far. Implementation of new characteristics on selection indexes will help increase efficiency of production to assure producers, packers and consumers more accurate results for their specific objectives.

Besides genetic selection, ruminant nutrition research has focused on strategies to improve animal growth performance and carcass quality. Different feed additives have been used to influence several characteristics on ruminants and some are used to modify growth. Ractopamine Hydrochloride is a metabolic growth modifier used to increase animal performance and has been used in cattle legally since 2003 in the United States of America (Gruber et al., 2007). Therefore, utilization of feed additives including ractopamine should be considered to improve not only production but also profit and carcass quality.

Another alternative to reduce costs in production and improve gain in the beef cattle industry has been the use of co-products of other industries such as ethanol,

beverage, food, forestry, cotton and citrus. Utilization of grain ethanol co-products has increased considerably recently as feed to livestock and it is still a growing area to be explored. Recent research has shown a higher energy value for corn co-products when compared to whole or dry rolled corn (Bremer et al., 2008), therefore the utilization of those feed is not only beneficial in an economic way but also in a nutritional way.

# CHAPTER II

# REVIEW OF LITERATURE I

## *Corn Production and Utilization in the USA*

According to USDA data and National Corn Growers Association (2010), corn is the third most important crop utilized in the world. The United States of America produced approximately 13.2 billion bushels of corn in 2009-2010 in approximately 80 million acres harvested. The U.S. is responsible for 42% of worldwide corn production (world production was 31.4 billion bushels), with an average of 165 bushels per acre and a gross crop value of 50 billion dollars (NASS-USDA Report, 2010). In 1974, national corn yield was estimated to be approximately 72 bushels per acre, compared to 165 estimated for 2009 in the same amount of acres (FAOSTAT, 2010) and yields are increasing with new technologies and advances in science.

Domestically more than 4200 different products are produced from corn and different process methods are utilized to reach those outcomes.

Wet, dry and modified distillers grains, solubles and wet corn gluten feed come from the milling processes and all are fed to livestock or exported. Different strategies of utilization of these co-products should be considered and one of them is the replacement of forage during adaptation to diets containing corn.

Continuous efficiency improvements and innovations have been reached by the ethanol industry and also by corn producers combining improved farming techniques,

research, and new technologies.

### *Ethanol Industry in the USA*

An exponential growth in ethanol production has been observed lately in the United States of America. Ethanol has become a common component of fuel supplies, confirming its economical importance for corn and co-products commodities in America. According to Stock et al. (2000) co-products from ethanol plants (either dry or wet milling plants) are highly variable due especially to use of different grain types or blend rates during fermentation. Different plants also have different outcomes, which affect the co-product composition. Corn is still the primary grain utilized in ethanol production, but other grains are also included as fractions or could be fermented independently such as sorghum, wheat, and barley.

Approximately 33% of the domestic corn production is being utilized for ethanol production. At the same time, distillers grains co-products are produced from that process as high energy and protein feed sources for livestock production. Feed components can be wet, dry or modified distillers grains, or corn gluten feed. Two major milling processes methods (dry milling and wet milling) are used for corn in the US. Ethanol can be produced by wet or dry milling methods. The majority of ethanol produced domestically in the U.S. is produced by dry milling plants. For further information on milling processes differences see Bothast and Schlicher (2005).

Ethanol production utilizes only the starch portion of the corn kernel. The remaining vitamins, minerals, protein and fiber are sold as a high-energy and protein value livestock feed.

Wet milling industry (Figure 1) produces a variety of products and some for human consumption forcing the utilization of corn grading number 1 or 2 only (Stock et al., 2000). Fines, residues and broken kernels are screened and removed, and the whole corn is steeped in sulfurous acid for approximately 2 days. After that, corn is ground, separated and centrifuged to isolate starch. Starch can be converted to dextrose and then to different products (corn syrup, fructose, etc) or to corn gluten meal. Distillers grains co-products are similar in composition with exception of fat content lower for wet milling plants and sulfur content variable among different plant processes. Corn germ, corn steep liquor and bran are produced during wet milling processes and they are the main components of the wet corn gluten feed (WCGF). Bran produced is pressed or dried to remove water until 40% DM approximately and steep liquor is incorporated to the bran creating WCGF that can be dried or pelletized. WCGF also varies within and across plants but the average values for DM, CP, NDF should be approximately 45, 20 and 38% respectively.

Dry milling industry (Figure 2) utilizes grains (mainly corn) as a starch source. The first step is to grind it, and cook it in high temperature water producing a mash. This mash then is chilled and dextrose is formed by enzymatic conversion. Yeasts for fermentation are added to the mixture and following fermentation and distillation a

product called whole stillage remains. Whole stillage undergoes centrifuging and that will result in distillers grains plus stillage. The remaining stillage liquid goes thru an evaporation and condensation process creating a product called condensed corn distillers solubles or syrup. Distillers grains or distillers solubles can be sold as ingredients or the solubles can be reincorporated creating distillers grains with solubles. Feed products are wet distillers grains with solubles (WDGS, approximately 35% DM), dry distillers grains with solubles (DDGS, approximately 90% DM) and modified distillers grains with solubles (MDGS, approximately 45% DM), and they should all contain approximately 11% fat, 30% CP, 38% NDF, 0.75% sulfur and 4.6% ash. Variation in DGS is commonly observed (Buckner et al., 2008) within plants with different loads and different grain type used in fermentation and among plants due to different processes and different amounts of solubles reincorporated to the distillers (Knott et al., 2004). Distillers solubles should contain about 20% fat, 24% CP, 2.3% NDF, 1.6% phosphorus and 0.9% sulfur (Erickson et al., 2007).

Estimated amounts of co-products produced and sold in 2009 were around 30.5 million metric tons, consisting of distillers grains, corn gluten feed and corn gluten meal, resulting from 10.6 billion gallons of ethanol production. The 30.5 million metric tons of feed generated by the industry in 2009 is equivalent to the total amount of grain fed to cattle in the nation's feedlots. Consequences of the ethanol production boost can be seen on many different categories for example corn price variation, exportation rates, domestic production, grain prices received by producers, etc. (Renewable Fuels Association, 2010).

It is valid to remember that ethanol production does not affect directly the amount of food available for human consumption since it is produced from field corn and not sweet corn fed to humans. Also, research it is being done to try to find alternative products for biofuels such as rice straw, sugar cane bagasse and corn stover, municipal solid waste, and energy crops such as switchgrass.

### *Ethanol Co-Products for Ruminants*

The utilization of grain co-products in beef cattle diets has increased throughout the years and because of the higher availability, its use has reached a larger number of producers in cattle feeding regions of the country. According to Vasconcelos and Galyean (2007) approximately 83% of nutrition consultants use some type of grain co-product in feedlot diets. Average utilization of DGS and CGF were around 17% of total DM of the diet.

According to Klopfenstein et al. (2008), the large use of corn-based ethanol co-products is due to the fact that DGS has approximately 3 times the nutrient concentration as the actual grain utilized for ethanol fermentation and production processes. Effects of feeding DGS on performance for beef cattle has been studied (e.g., Farlin, 1981; Firkens et al., 1985 Trenkle, 1996, 1997; Huls et al., 2008; Buckner et al., 2007) and even without the energy content of the starch, distillers grains have been shown to have more energy value than corn when replacing whole corn, DRC or HMC. The main factor affecting the use of DGS at the present time is price, followed by availability. Bremer et al. (2008)

reported that optimum levels for WDGS are between 20-40% depending on the diet, Huls et al. (2008) observed 30% for MDGS and Buckner et al. (2007) 20% for DDGS.

Meta-analyses demonstrate not only that DGS have greater feeding value than DRC and HMC, but also that feeding value is dependent on inclusion levels, DM content of the co-product, and type of grain processing. Combinations of DG and low quality forages presented positive results in performance and conditioning for cattle on feed prior to feedlot diets (Klopfenstein et al., 2008).

Ethanol plants are usually located in Corn Belt states where DRC and HMC are commonly used for feeding cattle, as compared to the Southern High Plains where SFC is more commonly fed. A concern that has intrigued researchers is the fact that use of WDGS in combination with SFC result in a lower performance response than when combined with DRC and HMC (Drouillard et al., 2005; Vander Pol et al., 2007; Corrigan et al., 2007).

Another concern about DG in finishing diets is the fact that even though WDGS and DDGS supposedly have the same nutrient composition, results show lower feeding values for DDGS compared to WDGS (124 and 147% respectively compared to corn) and also lower response for diets where DDGS replaced either DRC or HMC (Ham et al., 1994).

Feedlots also have the option of combining the uses of DGS and WCGF at the same time due to availability, nutrient profile and synergetic effects of those products.

***Modified Distillers Grains with Solubles***

MDGS is a product of the dry milling industry with similar composition to DDGS and WDGS but with an intermediate DM content (48-54% DM). Klopfenstein et al. (2008) reported that feeding values are lower for DDGS when compared to WDGS (8-31% difference) and that is probably due to drying process even though both have the same composition. Limited research has been done with MDGS but results showed greater DMI for treatments fed MDGS substituting for DRC and higher performance (ADG, G:F and Final BW) for animals fed MDGS and hay compared to corn silage (Trenkle, 2007b). Luebbe et al. (2008) observed greater ADG for yearling steers fed 15 and 30 % of MDGS substituting for corn compared to control corn-based diet, with calculated feeding values of 139 and 116% respectively. Final BW and HCW tended to be greater but no statistical difference was observed ($P < 0.10$).

Trenkle (2007a) reported greater feeding value for greater inclusions of MDGS in corn-based diets (47% of MDGS) compared to lower inclusions (24.9% of MDGS) with feeding value of 105 and 87% the value of corn, respectively. No carcass characteristics or performance measures were different for this experiment except G:F that was higher for the 47% MDGS treatment. DMI was lower for the same treatment when compared to no MDGS or 24.9% MDGS. However, during the following year Trenkle (2008) conducted an experiment with steers and heifers feeding 20, 40 and 60% of MDGS compared to the control corn-based diet and observed lower performance for the treatment receiving 60% MDGS. Feed efficiency and ADG were similar for the control,

20 and 40% MDGS treatments. Calculated feeding values for this trial were 98 and 91% value of corn for steers receiving 20 and 40% MDGS respectively and 90 and 95% for heifers. Past research showed that MDGS appears to present better results when fed in association with DRC or HMC compared when fed alone in the bunk (e.g., Trenkle, 2007a, 2007b, 2008).

***Wet Corn Gluten Feed***

Majority of WCGF found contains 20% CP, 38% NDF and 0.66% phosphorus. Cargill has a branded WCGF product called Sweet Bran® and it contains 60% DM, 24% CP, 37% NDF and 0.99% phosphorus (Stock et al., 2000; Erickson et al., 2007).

WCGF also presents variable composition within and between milling plants with exception of the Sweet Bran® (Cargill; Blair, NE) that offer a quality control program and consistency of the product on every load.

Ham et al., 1995, reported that WCGF is similar in $NE_g$ content to corn (Green et al., 1987), so may be used as a protein and/or energy sources in diets for cattle. WCGF contains highly and rapidly digested fiber fraction (DeHaan, 1983), and its protein escape is low (26%) due to rapid protein digestion of 9.5% per hour (Firkins et al., 1984).

Hussein and Berger (1995) compared relative energy values of WCGF to corn when feedlot heifers were fed ad libitum or 80% restricted diet based on residual feed intake. Feeding WCGF at levels of 25 or 50% of DM with corn-silage for ad libitum consumption, and 0, 25, 50 and 75% WCGF fed with HMC during growing phase were

tested. Results suggest that the most efficient level of corn substitution by WCGF were from 25 to 50% of dietary DM with no negative effects on feedlot performance, digestibility of nutrients, or carcass characteristics.

In two trials, Richards et al. (1998), reported that feeding up to 50% of WCGF replacing DRC had no impact on DMI (P > .10), increased gains (P < . 10) and efficiency (P < . 10) than calves fed the DRC control diets. Farran and others (2006) reported that steers receiving 35% WCGF on their diets with alfalfa hay had better performance than when no WCGF in diets with 0% alfalfa hay or or when alfalfa hay inclusion increased (less than 7.5% DM). Daily intake, ADG, and HCW increased linearly ($P < 0.05$) as dietary alfalfa hay level increased. Feeding 35% WCGF also increased DMI (P< .05) and tendencies for greater ADG and HCW (P < .10) compared to steers fed no WCGF.

Researchers at the University of Nebraska summarized 12 studies evaluating G:F of two different WCGF compositions and DM prior the year of 2000. The first WCGF tested contained wet bran and steep (approximately 41% DM, 17% CP, 48% NDF) and the second WCGF tested was composed of dry bran and steep (approximately 60% DM, 23% CP, 37% NDF). Both resulted in good performance with increased ADG and G:F, having a feeding value relative to corn of 101 to 115% (Stock et al., 2000).

### *Grain Adaptation Diets to Prevent Acidosis*

Ruminal acidosis has been and continues to be the most common digestive disorder observed in feedlots and that is because most of the beef cattle marketed in US

are fed grains in feedlots. Therefore, acidosis and consequently rate of starch digestion is an issue faced by the animals on a daily basis. Knowing that, adapting cattle to those high grain diets is important to avoid acidosis throughout feedlot feeding period. Any kind of organic acids accumulation can result in a dysfunctional balance between microbes and ruminal absorption and ruminal pH (Owens et al., 1998).

Ruminal and cecal anaerobic microbes are constantly converting carbohydrate substrates in volatile fatty acids (VFA) and lactate via fermentation for tissue metabolism (Sharp et al., 1982). Generally, ruminal fermentation can be considered stable if pH is higher than 5.5, and cattle adapted to high-concentrate diets are usually situated in a pH range of 5.6 to 6.5. Ruminal pH varies throughout the day and is influenced not only by diet but also individual buffer capacity, intake of fermentable carbohydrates and absorption of ruminal acids products (Nagaraja and Titgemeyer, 2007). In feedlots where carbohydrate supply is abruptly increased, a higher production of lactate and other volatile fatty acids in the rumen is observed and its accumulation can cause a phenomenon called acidosis (Dunlop and Hammond, 1965). Cattle fed forage-based diets or pasture usually do not appear to suffer from acidosis due mainly to the fact that intake is regulated by the physical gut fill versus a chemostatic regulation observed in cattle receiving high-concentrate diets. Acidosis in cattle fed high-grain diets can be separated into different types such as sub-acute (chronic) and acute. Its severity is related to amounts of grains fed, frequency, and duration, among other factors.

Sub-acute acidosis cases are the most common type observed and can be defined

by ruminal pH reaching values below 5.6 due especially to accumulation of VFAs and diminished bicarbonate input from bloodstream (Owens et al., 1998; Nagaraja and Titgemeyer, 2007). With ruminal pH below 5.6 an increase in VFA absorption is observed due to more protonation (Bergman, 1990). When this occurs, feed intake and performance are reduced without obvious signs of sickness exhibited by the animals (Cooper and Klopfenstein, 1996). Acute acidosis is different, where microbial changes in the rumen have been well documented. The changes under sub-acute are not well explained or documented especially during adaptation periods where microbial flora and fauna are forced to adapt to a new type of feed.

Acute acidosis is defined by pH levels below 5.0 due especially to accumulation of lactic acid and VFA in the rumen. Lactobacilli and *Streptococcus bovis* bacteria increase production of lactic acid. At the same time *Megasphaera elsdenii* decrease lactic acid utilization, leading to further declines in pH essentially because of the $pK_a$ values of the accumulated acids. Lactic acid has a pKa of 3.9 compared to 4.9 from VFAs (Nagaraja and Titgemeyer, 2007). According to Garza et al. (1989), osmolality in acidotic conditions are a lot higher than osmolality observed in normal metabolic conditions (as high as 515 mOsm/L vs. 290 mOsm/L respectively). Often damage such as ruminal and intestinal wall ulcers observed in the rumen is caused by acute acidosis. Also variation of plasma pH, due to increased rumen acidity could lead to serious health problems or death depending on the degree (Owens et al., 1998). Therefore, serious performance and economical losses will impact directly beef cattle production (Britton and Stock 1989; Nagaraja and Tiygemeyer, 2007). Processing methods for grains increases the rate of

digestion by microbes, therefore more acid can be produced in the rumen increasing the chances of acidosis in cattle (Stock and Britton, 1993).

According to various authors in the past (Britton and Stock, 1986; Cooper et al., 1998; Stock et al., 1990; Owens et al., 1998), feed intake decrease followed by lower performance are indicatives that acidosis may be affecting those animals. A decrease of ciliated protozoal population is another common observation in acidotic animals. More advanced cases may lead animals to sudden death, liver abscesses, secondary diseases, hoof problems, rumenitis, among others (Stock and Britton, 2006). Cooper et al. (1998) concluded that the majority of feedlot finishing cattle suffer acidosis to a certain extent during the adaptation or finishing periods.

Traditionally, several different methods have been utilized to adapt cattle to high-concentrate diets. Most popular step-up regimens used currently are three to four weeks due to research showing reduced performance for cattle adapted in 2 weeks or less (Brown et al., 2006). These step-up regimens are tools used to adjust rumen microbes and the animal to future readily fermentable carbohydrate diets, its products and its absorption. Decreasing levels of roughage and gradually increasing grain during adaptation is the primary method used by feedlots due to smaller changes in digestible energy density in the diets. Utilization of roughage in finishing diets are also a method to control acidosis (Stock et al., 1990). The majority of feedlots would like to eliminate the usage of roughage due to numerous management challenges such as space, handling, mixing problems, and reduced feeding efficiency. Therefore, trends for diets in feedlots

have been to feed minimal amounts of forage and maximum amount of concentrates (small particle size), which can increase the risk of acidosis.

Therefore, adaptation is a practical and critical management practice that may influence present and future performance of animals on finishing diets. Fulton et al. (1979a, 1979b) evaluated adaptation to concentrate diets by beef cattle and concluded that wheat diets affect pH more than corn diets, ruminal pH decreases when starch increases throughout the adaptation period. Roughage type and particle size are important in adaptation. Studies conducted by Mader et al., (1991) and Brown et al., (2006) adapting cattle with larger particle size roughage have reported more positive results compared to smaller particle size (same used in finishing diets where performance needs to be greater), however the utilization of WCGF and other corn co-products may be a feasible alternative to adapt cattle to high concentrate diets even though particle size is small in WCGF (Huls et al., 2009; Rolfe et al., 2010). Utilization of WCGF to reduce subacute acidosis in cattle was evaluated by Krehbiel et al. (1995) in two experiments and they concluded that WCGF did not eliminate acidosis but reduced the length of time exposed to lower pH. Also the use of WCGF can minimize roughage utilization in feedlots. Huls et al. (2009) conducted a 33 day metabolism trial comparing traditional adaptation starting with 45% of diet DM as alfalfa hay, and decreasing to 7.5% of the diet DM, and also decreasing levels of WCGF (SweetBran®, Cargill, Blair – NE) from 87.5% of DM to 35% of DM in the finishing diet. Animals adapted with WCGF had greater DMI (21.78 vs. 16.14), *in situ* DM digestibility, and lower pH values compared to traditional forage diets (5.84 vs. 6.28); however, mean pH values were greater than 5.8

which is considered safe for acidosis. Also a feedlot trial was conducted to determine economical feasibility and performance using WCGF to adapt cattle instead of forage. Treatments were applied only during a 26 day adaptation period and all steers were fed a common diet for 147 days containing 35% WCGF. Steers from the WCGF treatment had greater ADG and greater G:F, and no effect on carcass quality comparing the two treatments was observed. Profits were greater for steers adapted to finishing diets using WCGF compared to using alfalfa hay. Rolfe et al. (2010) conducted a 35 day metabolism trial using the same approach but using WDGS instead of WCGF, with WDGS decreased from 87.5% to 35% of dietary DM. Control steers had greater initial DMI and average ruminal pH compared to WDGS treatment; however, both treatments appeared to adapt cattle to the finishing diets.

Acidosis is always going to be present in the feedlot industry causing reductions in performance and economics. Grain adaptation strategies may positively influence acidosis and performance of feedlot cattle. Different methods, management and feed sources should be considered by beef cattle producers especially with higher availability of corn co-products from ethanol plants compared with the desire to feed as little forage as possible.

Figure 1. Wet Milling Industry Process.

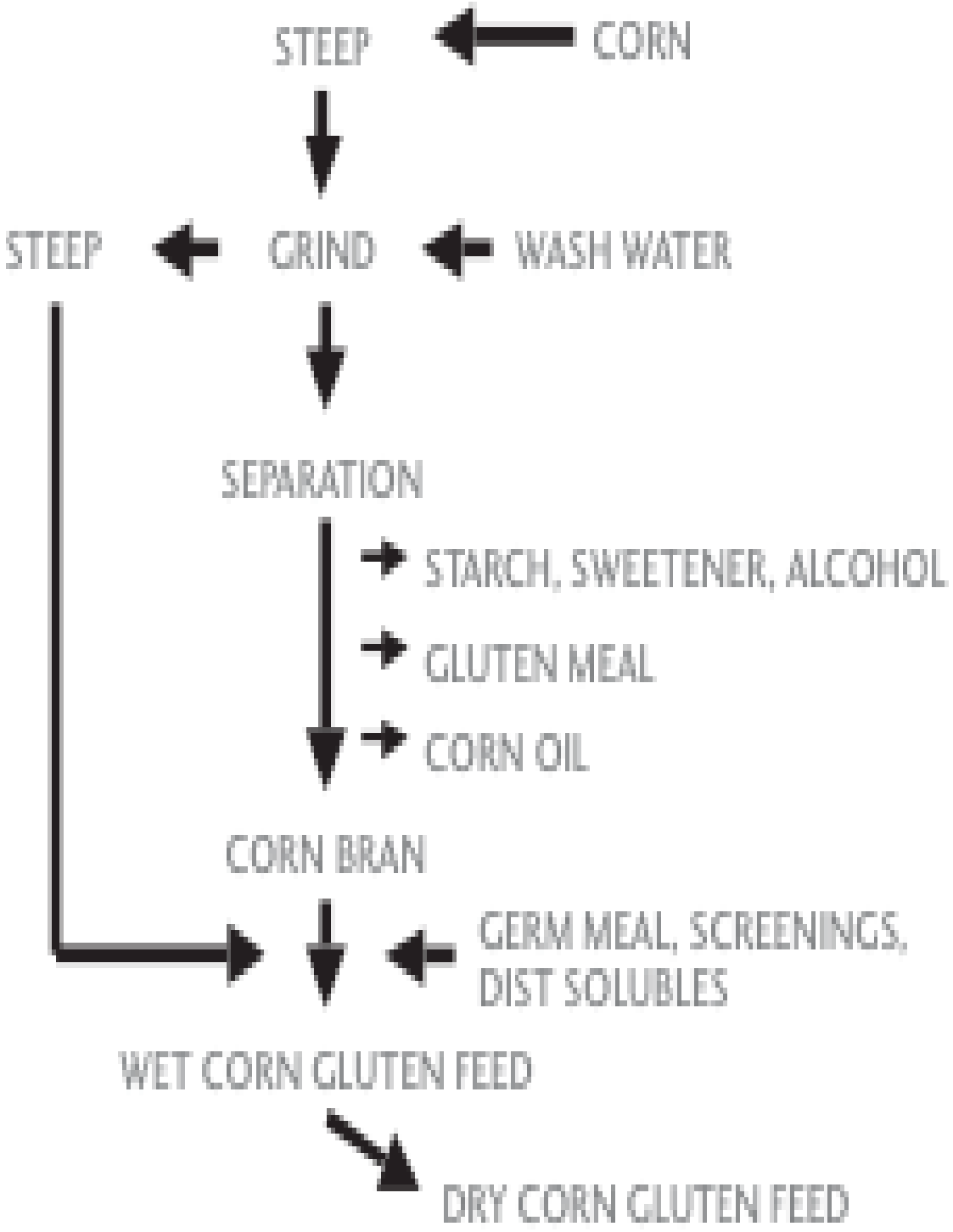
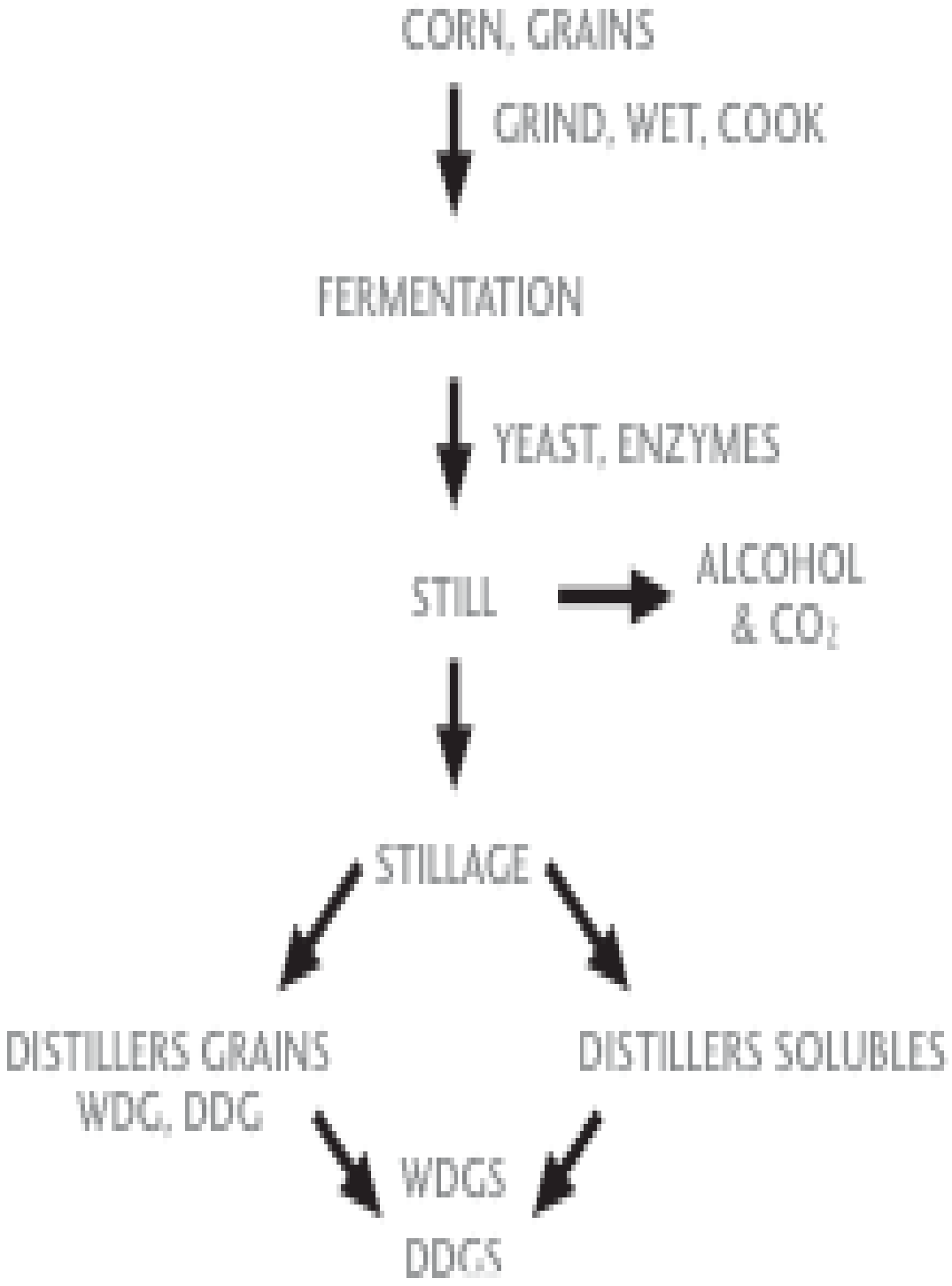


Figure 2. Dry Milling Industry Process.



# REVIEW OF LITERATURE II

## *β- adrenergic agonists in Livestock*

Livestock research has been focused in several different groups of feed additives with the objectives of enhanced production, maximizing profit, and improving feed efficiency. Beef cattle production research has shown interest in different metabolic modifiers that influence or modify growth rate and composition of growth (NRC, 1994). Ractopamine Hydrochloride is a β- adrenergic agonist, that can be defined as a repartitioning agent that redirects and increases nutrient flow from fat deposition towards muscle deposition (Ricks et al., 1984).

## *Characterization of Ractopamine Hydrochloride*

Ractopamine hydrochloride, a phenethanolamine derivate also described as *β*-adrenergic agonist that chemically can be related to catecholamines, epinephrine, and norepinephrine (Bell et al., 1998), have been approved for use in beef cattle to enhance growth performance in feedlots.

As part of a synthetic group of anabolic steroids, this compound generally increases protein accumulation, enhances growth performance, and may affect adipose tissue deposition, depending on the dose and diet by ractopamine interactions (Xiao et al., 1999; Abney et al., 2007). In 2003, the USDA approved Ractopamine hydrochloride for use in commercial beef cattle production in the United States. Subsequently, many studies have been performed to improve understanding about its effects on finishing cattle.

To understand the results of metabolic and performance studies, it is first necessary to know how the $\beta$- adrenergic agonists work (especially ractopamine hydrochloride). When ractopamine or other $\beta$- adrenergic agonists are administered to an animal, a physiological response occurs due to the binding reaction between $\beta$- adrenergic agonist and the $\beta$- adrenergic receptors. There are three types of $\beta$- adrenergic receptors, $\beta_1$, $\beta_2$ and $\beta_3$. All types are generally present on most mammalian cells, with varied distribution depending mainly on given tissue and species. Therefore, differences in physiological response may be observed due to the large number of effects involving the role of $\beta$- adrenergic receptors, dietary factors, and animal characteristics (Mersmann, 1998). Animal species that are closer to the biological maximal growth rate, such as some swine and chicken breeds due to intensive selection for growth, may present less response than ruminants which may possess a higher potential to increase growth or simply have better response by particular $\beta$- adrenergic receptors (Mersmann, 1998).

The compounds known as $\beta$- adrenergic agonists are organic molecules that have the ability to bind to $\beta$- adrenergic receptors and start biochemical reactions that will result in different outcomes. The $\beta$- adrenergic agonist in discussion, ractopamine hydrochloride, is more specific and generally used to improve the performance of finishing animals (Abney et al., 2007).

Byrem et al., 1998, reported protein accretion in vivo due to a direct response to the $\beta$- adrenergic agonist (cimaterol). This anabolic response was temporary, with a peak time occurring during the first 14 days. The response was considerably attenuated by 21 d

of treatment.

This phenomenon may be explained by the desensitization of the $\beta$-adrenergic receptor, due to $\beta$-adrenergic agonist duration of exposure (Hausdorff et al., 1990). This phenomenon have been studied data available confirm that depending on administration time and dose of $\beta$-adrenergic agonists, different responses are observed on growth performance and carcass characteristics such as weight gain, fat deposition and longissimus dorsi muscle throughout the time (e.g., Sainz et al., 1993, Williams et al., 1994). Desensitization of $\beta$-adrenergic receptors mainly affects two pathways: $G_s$ protein and adenylyl cyclase (cAMP). These pathways catalyze cyclic adenosine phosphate (major intracellular signaling molecules) formation from ATP, leading to a plateau of the levels of cAMP after constant stimulation (Hausdorff et al. 1990). Two main different desensitization processes were described by Hausdorff et al. (1990), short or long-term, and both suggested a decrease in response by the receptors. The short-term desensitization is caused by the rapid attenuation of the adenylyl cyclase response that disappears in minutes after removal of the desensitization agonist and do not require new protein synthesis. Long-term desensitization is a more complex process that mostly requires new protein synthesis and may take several days for total recovery.

### *Early Research on Ractopamine Hydrochloride Fed to Livestock*

First starting in the late 1970's with the first patents in mid-1980's, $\beta$- adrenergic agonists have been studied intensively throughout the years. Several authors have reported results on utilization of ractopamine hydrochloride and other $\beta$- adrenergic

agonist in livestock since 1983 with the majority of work done using swine as the study specie. This was because of the first objective of $\beta$- adrenergic agonist research, which was attempt to solve the problem of excessive fat deposition in the livestock. Early studies with $\beta$- adrenergic agonists utilized many different compounds such as clenbuterol, cimaterol, ractopamine, salbutamol, zilpaterol, etc. The majority of these studies reported divergent results due specifically to different compounds, animal genetic lines, and dosage of $\beta$-agonist.

Baker et al. (1984) used clenbuterol in high-concentrate diets for lambs on three, 8-week treatment experiments. One of the studies showed no effect on weight gain, but an improvement in feed efficiency. No statistical performance differences were observed on the second experiment, although gain and efficiency were numerically higher for the treated groups compared to controls. The third experiment showed an increased rate of gain of 24.1% and improved feed conversion of 19.1% when compared to controls. Heavier carcasses and increased dressing percentages were observed in all experiments for treated animals receiving β-agonists compared to controls. Decrease in kidney and pelvic fat were also reported with a range of 10 to 34% less than the control. Increases of 25 to 45% in *Longissimus dorsi* muscle area were also observed for treated groups. Fat thickness decreased in one of the experiments by 37%. Veenhuizen et al. (1987) reported an increase in the rate of gain and feed conversion for pigs fed phenethanolamines for 10 days. Animals were harvested at an approximate equal weight and larger *Longissimus dorsi* muscle area was observed in treated groups compared to controls. Less fat depth on the $10^{th}$ rib was reported. Phenethanolamines were considered effective for growth and

improving carcass composition in pigs.

Effects of ractopamine were studied by Anderson et al. (1987) in 8 trials with finisher pigs. Ractopamine increased nitrogen retention in a range of 12 to 19% when compared to controls and blood urea nitrogen was reduced by 10 to 13% for treated groups and digestibility was not affected. Animals receiving ractopamine showed increases in ADG, feed efficiency, *Longissimus dorsi* muscle area, dressing percentage, and a decrease in fat thickness on the $10^{th}$ rib. Smith et al. (1987) found that ractopamine had some effects on specific genes that stimulate protein synthesis, explaining several results of increases in *Longissimus dorsi* muscle area. The same improvements and trends on performance and carcass characteristics were confirmed by Crenshaw et al. (1987) and Hancock et al. (1987).

Different levels of ractopamine hydrochloride were tested by Watkins et al. (1990) on performance and carcass characteristics of finishing swine. Nine studies were conducted in different geographical areas of the United States and results showed an increase of ADG and feed efficiency in all of them. Dressing percentage, *Longissimus dorsi* muscle area, estimated fat-free muscle and dissected lean muscle were also improved for all treatments receiving ractopamine. In 1994, Williams et al. evaluated the impact of ractopamine on pig growth and carcass merit and these results confirmed that ractopamine improved ADG for both barrows and gilts. Pigs treated with ractopamine additionally had faster weight gain with less feed than non-treated groups. Maximum response for ractopamine was observed between test days 7 and 21. A plateau was reached and a linear decline in response was observed at this time. Ractopamine reduced

carcass fat thickness at the 10th rib and improved *Longissimus dorsi* muscle area.

Xiao et al. (1999) studied the effects of ractopamine at different dietary protein levels on growth performance and carcass merit in finishing pigs and reported an increase in ADG of 9% and feed efficiency of 14% for the high protein group compared to the control, however the low protein group did not differ from the control. Higher carcass lean proportion of 4.5%, increase of *Longissimus dorsi* muscle area, decrease in fat composition and fat depth on the10th rib, were observed in all ractopamine treatments independent of the dietary protein group.

***Present Research on Ractopamine Hydrochloride Fed to Beef Cattle***

After 2004, research data has been published on the effects of ractopamine on beef growth performance and carcass characteristics (e.g., Vogel et al., 2005; Van Koevering et al., 2006a, 2006b; Schroeder et al., 2005a, 2005b; Crawford et al., 2006; Laudert et al., 2005a, 2005b), and in general increase of body weight was observed for treatments that administered ractopamine against the controls with no ractopamine.

Gruber et al. (2007) conducted a study with different biological types of steers (British, Continental crossbred and Brahman) examining the effects of ractopamine hydrochloride on growth performance and carcass characteristics. Ractopamine was fed during the last 28 days prior harvest in a dose of 200mg/head daily to the treatment group and no ractopamine was offered to the control. No interaction between biological type and ractopamine was observed. Ractopamine improved ADG and G:F and did not affect DMI of steers agreeing with Laudert et al. (2005a) and Schroeder et al. (2005a). No effect on

dressing percentage, fat thickness, KPH and yield grade was observed. Heavier carcass and larger *Longissimus dorsi* muscle area was reported for animals receiving ractopamine, these results were also observed by Laudert et al. (2005b), Schroeder et al. (2005b), Vogel et al. (2005), Van Koevering et al. (2006a) and Crawford et al. (2006). Greenquist et al. (2007) evaluated various durations of ractopamine in finishing steers. Treatments had 0 or 200 mg/head daily and 28 or 42 days immediately prior harvest. Results showed that feeding 200 mg of ractopamine per head daily increased live BW, ADG and feed efficiency compared to control. Most of the gain response to the $\beta$-adrenergic agonist (87%) was observed for the 28 days treatment when compared to 42 days receiving ractopamine. Improvement of HCW was observed, but no differences on dressing percentage, $12^{th}$ rib fat thickness, *Longissimus dorsi* muscle area, marbling score and calculated yield grade were reported. Similar responses were reported by Walker et al. (2006) when feeding 200 mg/head daily during 28 days for feedlot heifers.

Also in 2007, Abney et al. presented a study that analyzed the effects of ractopamine on performance, rate and variation in feed intake and acid-base balance in feedlot cattle. Treatments consisted of doses of 0, 100 or 200 mg/steer daily and durations of 28, 35 or 42 days prior harvest. No interactions between dose and duration were detected. As ractopamine dose increased, a linear response for live BW, ADG and G:F was detected agreeing with past research. For longer feeding durations, ADG had a quadratic response and tendencies for live BW and G:F were also observed. HCW was increased linearly with increases of dose. Agreeing with Greenquist et al. (2007), optimum response to ractopamine was observed within the first 35 days of feeding the compound with little

response from 35 to 42 days. For acid-base balance and intake, no difference on urine pH, blood gas measurements, or rate of intake were observed. For carcass characteristics, animals receiving ractopamine presented larger *Longissimus dorsi* muscle area and decreased yield grade. Optimal performance was provided by the 200mg/head daily during 35 days prior to harvest.

***Intermittent Feeding of Ractopamine Hydrochloride***

Based on desensitization of $\beta$- adrenergic receptor research, the hypothesis that intermittent feeding of $\beta$- adrenergic agonists could enhance response on growth performance was created. Neill et al. (2005) conducted two experiments that consisted of different regimens of ractopamine treatments in late finishing pigs. Experiment 1 had four treatments, the control with no ractopamine for 56 days, 21 days of ractopamine plus 35 days of control, 21 days of ractopamine plus 14 days of control plus 21 days of ractopamine, and 35 days of control plus 21 days of ractopamine. Experiment 2 had five treatments with a control with no ractopamine for 56 days, ractopamine fed for 56 days, 21 days of ractopamine plus 14 days of control plus 21 days of ractopamine, control fed for 7 days plus ractopamine fed for 21 days plus control fed for 7 days plus ractopmaine fed for 21 days, and 35 days of control plus 21 days of ractopamine. Results did not show a difference in ADG or feed efficiency comparing continuous against intermittent feeding, but higher values for final BW were observed in some cases for intermittent feeding of ractopamine over continuous feeding.

Research with $\beta$- adrenergic agonists have shown several benefits to producers,

packers, processors, consumers, and environment. More efficiency in meat production presents a large area of future concern without affecting carcass quality. $\beta$- adrenergic agonists may be used as an important practice if economically viable at the present situation. Consumers may benefit from leaner products with less cholesterol and reduced calories. Land productivity will improve and increased nitrogen retention in animal tissue growth may result in less nitrogen excreted as waste to the environment. Intermittent data are not available for beef cattle, however data reported from swine research have shown improvements on growth performance and carcass characteristics.

# REVIEW OF LITERATURE III

## *Genetic Parameters of Mature Size in Beef Cattle*

Mature size in beef cattle is an important trait to be considered in genetic selection programs and can be described as different related measures of weight, height and body condition score at maturity. The potential impact on profitability in beef enterprises has led researchers to estimate genetic parameters of these traits using various statistical models (Northcutt and Wilson, 1993; Kaps et al., 1999; Arango et al., 2002; Rumph et al., 2002). Generally full models are used for this kind of analysis including direct and maternal genetic effects, direct permanent environmental, and maternal permanent environmental random effects, however other models may be used without including maternal effects. Lifetime growth has also been estimated accounting for mature cow weights and heights (Johnson et al., 1990), and has utilized in genetic programs in different beef cattle associations, such as the American Angus Association, Holstein Association USA, etc.

According to Morris and Wilton (1976) mature size directly influences production efficiency. Important relationships exist between mature size and maintenance requirements (McMorris and Wilton, 1986). It is known that mature body size has a genetic component but different environmental factors may alter this trait as well such as nutrition and hormonal regulation during fetal development and throughout the life (Owens et al., 1993). Therefore accounting for other factors other than the genetic aspect is necessary for a successful and profitable production system. Many economical

characteristics are directly related to mature size such as reproduction (Olson et al., 1994), and cull cow value.

Positive genetic trends for weaning and yearling weights have been observed in the past but have begun to plateau recently (AAA, 1998; 2010). This has created a correlated increase of mature size that may be undesirable due to an increase in maintenance energy requirements (Buttram and Willham, 1989). Bullock et al. (1993) reported correlations between immature growth traits and mature weight of 0.80, 0.89, 0.73, and 0.76 for weaning weight, yearling weight, yearling height and 205 to 365 d gain, respectively. Northcutt and Wilson (1993) reported genetic correlations ranging from 0.66 to 0.78 using different models and 0.54 to 0.58 for phenotypic correlations for mature weight (MW) and mature height (MH), respectively. Arango et al. (2002) reported genetic correlations between cow weight and height of 0.80, cow height and cow weight adjusted for body condition score of 0.86, and for the same pair of traits phenotypic correlations were 0.59 and 0.64, respectively.

The American Angus Association conducts genetic evaluations and publishes expected progeny differences (EPD) for mature weight and mature height using animal model with predicted 6 years old weights (AAA, 2010). Body condition score is considered and included in the cow weight data. To accommodate differences in weight due to differences in body condition, the records are adjusted to a body condition score five (AAA, 2010). Cow hip heights, weight and body condition are measured at weaning. Yearling weights are an important component in calculations of mature size EPD due to moderate genetic correlations with mature traits. These same EPD help to estimate size

of cows at six years of age. Mature weight (MW) and height (MH) are highly heritable traits. Northcutt and Wilson, 1993 reported heritabilities ranging from 0.45 to 0.51 for MW and 0.83 for MH. Bullock et al. (1993) estimated heritability of 0.52 for MW and Arango et al. (2002) reported heritabilities for MW ranging from 0.47 to 0.58 and 0.59 to 0.72 for MH.

Selection programs should be developed carefully and take in to consideration many factors such as management practices, environmental constraints, and production goals.

According to Montano-Bermudez et al. (1990), the two main variables that influence the ability of a cow to meet maintenance nutrition requirements are milk production and body weight. Increased cow weight or milk yield compared across different biological types was associated with increased weaning weight by McMorris and Wilton (1986). Differences in feed efficiency can be observed between different breed crosses and these differences are probably associated with genetic potential for milk yield and mature weight as shown in results reported by Jenkins et al. (1991). Cows that produced heavier calves required more energy to maintain BW during the lactation period. Therefore, cows with a higher genetic potential for milk production need more nutrients than cows with a lower milk production potential.

The combination of EPD (genetic index) for milk production and mature size may help breeders reach their production goals accounting for costs of maintenance requirements. Therefore, accurate estimates of genetic and environmental variances to use in computing EPD are necessary for that to happen. It is also necessary to consider

correlated responses between mature size and other traits. Knowledge of genetic correlations is necessary to prevent undesirable changes in other traits, as an example, genetic and phenotypic correlations between growth and carcass characteristics with economic importance should be considered (Woldehawariat 1977).

Several studies have estimated the effect of increasing of mature weight on preweaning weights, feedlot weights, and market traits. According to Jones et al. (1982), an increase of 100kg in cow weight resulted in 19 kg of added cold carcass weight. However calves had to stay on feed for 2 more weeks to reach a desired slaughter point. Also an increase of 100 kg in milk yield only gave 2.5 kg in additional slaughter weight suggesting only a very small maternal component to carcass weight. Dressing percentage and marbling score were not affected by cow weight, however an increase of 1 mm of fat thickness of the dam gave an average reduction of 4.3 days on feed and a decrease of 5.7 kg in slaughter weight. In summary larger cows produced older and heavier cattle at slaughter but little effect on meat quality was observed (Jones et al., 1982).

High correlations (genetic and phenotypic) between measurements of early growth (birth weight and weaning weight) have been estimated in the past. McMorris and Wilton (1986) observed that cow weight and milk yield are positively correlated to calf birth weight and weaning weight. Results for calving ease were not significantly different when associated with cow weight for any of the breeding systems. Calving ease may be more associated with cow height (Bellows et al., 1982).

Cows with increased mature size would be expected to produce bigger calves that would possibly gain weight more rapidly and have increased feed intake. No difference

was observed for gain in feedlot (e.g., Marshall et al., 1976; Nelson et al., 1982; McMorris and Wilton, 1986) but greater values for cow weight were associated with increased weaning weight, both within and across breeds. Changing cow weight had no significant effect on calf creep feed intake. No significant effects were reported for days on feed, ADG, gain on feed, feed intake, or market weight in any of the breeding systems analyzed. Larger cow size however was associated with heavier final body weight at harvest and longer days on feed due to greater maintenance nutritional requirements (e.g., Klosterman et al., 1968; Jones et al., 1982; McMorris and Wilton, 1986).

Reproductive efficiency is another important trait and its association with mature size should be considered because of its economical importance to beef production. If breeders decide to keep increasing mature size they need to have knowledge of the consequences that may come with this decision. Reproductive performance, as well as economic and market strategies should drive decisions related to cow size along with production management, feed availability, maintenance requirements and environment conditions. In conclusion, numerous factors should be considered associated with mature size in a selection program. Mature weight and mature height would respond favorably to selection as shown by previous studies. Direct heritabilities estimated have been reported from moderate to high and selection for one would lead to correlated response in the other.

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# CHAPTER III

**Effects of Feeding a Combination of Modified Distillers Grains With Solubles and Wet Corn Gluten Feed to Adapt Cattle to Finishing Diets**

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## ABSTRACT

Two 39-d metabolism studies and 1 feedlot experiment were conducted to evaluate the efficacy adapting beef cattle to finishing diets using 2 different strategies: a combination of modified distillers grains and wet corn gluten feed (COPRODUCT; (Synergy; ADM, Columbus, NE)) or the traditional approach of decreasing the proportion of dietary forage (CON). In Exp. 1, six yearling steers (BW = 405 kg $\pm$ 20) fitted with ruminal cannulas were used in a completely randomized design experiment. The same design and treatments were used in Exp. 2, with six ruminally cannulated calf-fed steers (BW = 256 kg $\pm$ 14). Dry matter intake expressed as % of BW tended to be greater for steers on traditional grain adaptation with forage compared with COPRODUCT during the first step of adaptation ($P = 0.09$ for Exp. 1, and $P = 0.14$ for Exp. 2), but DMI did not differ between treatments in subsequent adaptation diets (steps 2, 3 and 4). Average ruminal pH was less with the COPRODUCT treatment for steps 1 and 2 compared with CON in Exp. 1, with no treatment differences in average pH for

steps 3 and 4. No differences were observed in Exp. 2 for average pH during any of the adaptation steps. Both adaptation methods resulted average ruminal pH values that were greater than 5.6 and $H_2S$ concentrations that were < 36μmol/L of gas. Dry matter digestibility (DMD) differed ($P = 0.05$) between treatments during step 1, with increased DMD for the COPRODUCT treatment. In Exp. 3, two hundred and thirty six steers (BW = 429 kg $\pm$ 0.6) were utilized in a completely randomized block design and fed the two treatments during the adaptation and a common diet throughout the finishing period until harvest. In the feedlot experiment, live and carcass-adjusted performance did not differ between treatments. Carcass characteristics did not differ between treatments except for calculated dressing percent, with greater values for the CON treatment. Adaptation period performance was superior for cattle in the COPRODUCT treatment group compared with CON, with differences in DMI (less for COPRODUCT; $P < 0.01$) and G:F (greater for COPRODUCT; $P = 0.04$). Results indicate that a combination of MDGS and WCGF can be used to adapt beef cattle to finishing feedlot diets with same efficacy as the traditional forage-based method.

**Key Words**: Acidosis, adaptation, corn co-products, wet distillers grains, wet corn gluten feed

## INTRODUCTION

Ruminal acidosis continues to be the most common digestive disorder observed in feedlots. Adapting cattle to feedlot finishing diets is an important management tool used to avoid sub-acute to acute acidosis. Acidosis can negatively affect production through

decreases in growth performance mortality in severe cases (Owens et al., 1998; Nagaraja and Titgemeyer, 2007). With an exponential increase in ethanol production in the USA, corn coproducts are an important feed alternative for beef cattle production systems. Klopfenstein et al. (2008) reported that corn coproducts from ethanol production are excellent feed sources for energy and protein and can be used effectively in different combinations. Previous studies reported decreased acidosis when wet corn gluten feed was fed (e. g., Krehbiel et al., 1995). Results of metabolism and feedlot research using wet corn gluten feed (Sweet Bran; Cargill Corn Milling, Blair, NE) to adapt beef cattle indicated that starting with a high concentration of Sweet Bran and decreasing Sweet Bran instead of forage is a viable method for adapting feedlot cattle to feedlot finishing diets (Huls et al., 2009). A metabolism trial was conducted using wet distillers grains with solubles (WDGS) to adapt cattle (Rolfe et al., 2010). and results suggested that WDGS can be used instead of forage; however, performance data were not reported, and DMI was initially less for the WDGS treatment. Sarturi et al. (2011) compared WCGF and WDGS for adapting cattle to finishing diets and concluded that cattle fed WCGF had greater DMI and a greater average ruminal pH than cattle fed WDGS during adaptation.

Our objective was to test a combination of modified distillers grains with solubles (MDGS) and wet corn gluten feed (WCGF) with respect to changes in ruminal pH, intake, $H_2S$ concentration in ruminal gas, in situ fiber digestibility, DM digestibility, and performance and carcass characteristics of finishing beef cattle compared with a traditional forage-based method of cattle adaptation to finishing diets. The combination

of MDGS and WCGF was similar to a new feed produced by ADM (Synergy; Columbus, NE).

## MATERIAL AND METHODS

All experiments were conducted according to animal care procedures approved by the University of Nebraska Institutional Care and Use Committee.

### *Experiment 1*

#### *Location, animals and management*

Six yearling crossbred steers (BW = 405 $\pm$ 20 kg) fitted with 10 cm ruminal cannulas were removed from pasture following summer grazing to serve as a model of yearling cattle entering a feedlot. Steers were assigned randomly into 1 of 2 adaptation treatments in a CRD with 3 steers/treatment. Before transport from the University of Nebraska-Lincoln Agricultural Research and Development Center (Mead, NE) to the Metabolism Facility at the Department of Animal Science UNL (Lincoln, NE), animals were grazed brome grass in a single pasture. One week before the start of the experiment, the steers were fed 9 kg/d of bromegrass hay (DM).

#### *Experimental design and experimental treatments*

Animals were weighed and stratified by BW and assigned randomly to the 2 treatments. Adaptation period diets for the COPRODUCT and control (CON) treatments are shown in Table 1. The COPRODUCT steers were fed decreasing levels of the MDGS and WCGF combination (87.5 to 30%), whereas CON steers were fed using traditional grain adaptation diets with decreasing forage from 45 to 7.5% (Table 1). In

both adaptation schemes, dry-rolled corn increased (up to 57.5%) as the coproduct or roughage decreased. Cattle were fed ad libitum once daily. Five adaptation diets were used to increase corn with diets fed 9, 7, 7, 7, and 9 d, respectively. The final 9-d period consisted of a common finishing diet containing the COPRODUCT combination at a level of 30% of dietary DM. Supplements provided 360 mg/steer of monensin (Rumensin, Elanco Animal Health, Indianapolis, IN), 90 mg/steer of tylosin (Tylan, Elanco Animal Health), and 150 mg/steer of thiamine daily (Table 1). Treatment diets were formulated to meet or exceed the NRC (1996) requirements for CP, Ca, K and P. Feed analyses are presented on Table 2. Cattle were housed in individual pens (1.5 m x 2.4 m) with slotted floors and rubber mats, and water was available free choice. Room temperature was constant at 25°C.

***Data collection***

Steers were fed once daily at 0800 and feed refusals were collected, frozen at -20°C, composited by steer and period, and dried to calculate DMI. Methods for data collection of feed intake and ruminal pH at the metabolism facility was described previously by Cooper et al. (1999), Erickson et al. (2003), and Vander Pol et al. (2009). Intake and pH (wireless pH probes; described below) measurements were collected every minute during the study. Feed intake data were collected through bunks with suspended load cells (Omega Stamford, CT) for weigh measurements and recorded (Labtech, Wilmington, MA) on a computer connected to the feed bunk.

Ruminal pH data were collected using a submersible pH probe (Sensorex, Stanton,

CA). Probes were placed inside the rumen via cannula and remained suspended in ruminal fluid for 7 d during each adaptation step period. For steps 1 and 5, data from the last 7 d were collected. Average pH, maximum and minimum pH, pH variance and, time and area below 5.6 and 5.3 were analyzed using procedures of SAS (SAS Inst., Cary, NC, USA).

Ruminal gas samples were collected 8 h after feeding on the last 2 d of each period, and $H_2S$ concentrations were analyzed using the procedures described by Kung et al. (1998). Gas was collected by inserting a pipette through the cannula and collecting 20 mL of gas into a syringe with a 21-gauge × 3.8-cm needle five consecutive times. From the total gas collected, 5 mL was placed to a glass vial containing alkaline water (pH = 8). A ferric chloride solution then was prepared and also a solution of N-N-dimethyl-p-phenylenediamine (DPD) was prepared. The DPD and the ferric chloride solutions were added to the vials in 0.5 mL volumes. Samples then were allowed to react for 30 min at 25°C. A standard curve was developed using standards prepared before data collection, and a regression equation from the standard concentrations and absorbance values were used to calculate the $H_2S$ concentration (μg/mL) in each culture vial.

In situ NDF digestibility data were determined with dacron bags (50 μm pore size; 5 x 10 cm; Ankom, Fairport, NY) containing alfalfa and corn bran incubated for 24 and 32 h (incubation times based on past studies). Both alfalfa and corn bran for the samples were ground to 2-mm particle size. In situ incubations started either at 800 or 1600 h, with samples removed at 1600 h of the next day. After removal, bags were machine washed according to methods of Vanzant et al. (1998) and Whittet et al. (2002) (5 cycles

of 1 min of agitation and 2 min of spin per cycle) and frozen (-20° C) and stored until analyses. For analyses, bags were thawed and washed, analyzed for NDF using an Ankom unit (Ankom, Fairport, NY) and dried in a 60°C oven with forced-air circulation for 48 h to determine NDF disappearance.

Total tract DM digestibility was determined with chromic oxide ($Cr_2O_3$) as an internal marker dosed via the ruminal cannula at 7.5g at 0700 and 1700 h daily during every day of the first and last period of the study. Fecal samples were collected at 0600, 1200, and 1800 h on d 6, 7, 8 and 9 (step 1) and also d 36, 37, 38 and 39 (final period). Fecal samples were composited by day and period and then analyzed via atomic absorption spectrophotometer for quantification of chromium. The quantification was estimated via air-acetylene flame (Varian model SpectrAA-30; Varian Techtron Ltd; Georgetown, Ontario).

***Statistical analyses***

Data were analyzed using the GLIMMIX procedure of SAS (Version 9.2, SAS Inst. Inc., Cary, NC). Steer was the experimental unit, and the residual was used to test for treatment effects. Variables DMI and ruminal pH were analyzed as repeated measures using an autoregressive (AR(1)) covariance structure with day being the repeated measure. The model for those 2 traits included period, dietary treatment, and day of collection. Ruminal $H_2S$ concentration, in situ fiber digestibility and total tract DM were also analyzed as a RCBD with the model including period and treatment. Least square means were separated using the PDIFF statement in SAS when protected by a significant F-test ($P<0.10$).

***Experiment 2***.

To model calf-fed steers, 6 ruminally cannulated (10 cm cannula) steers (BW = 256 $\pm$ 13 kg) were used to measure DMI, ruminal pH, and total tract DM digestibility. The same diets (Table 1) and methods of data collection, and laboratory and statistical analyses described for Exp. 1 were used to Exp. 2, except that $H_2S$ concentration and in situ NDF digestibility were not measured on Exp. 2. One animal of the COPRODUCT treatment was removed because of health problems. Data collected from this animal were not used in any of the analyses.

Data were analyzed using the GLIMMIX procedure of SAS (Version 9.2, SAS Inst. Inc., Cary, NC). Steer was the experimental unit, and the residual was used to test for treatment effects. Variables DMI and ruminal pH were analyzed as repeated measures using an autoregressive (AR(1)) covariance structure with day being the repeated measure. The model for those 2 traits included period, dietary treatment, and day of collection. Ruminal $H_2S$ concentration, in situ fiber digestibility and total tract DM were also analyzed as a RCBD with the model including period and treatment. Least square means were separated using the PDIFF statement in SAS when protected by a significant F-test ($P<0.10$).

***Experiment 3***.

***Location, animals and management***

Crossbred, yearling steers received on October 2009 were grazed corn stalks during the winter. Two months prior trial start, animals were located in a dry lot. The yearlings

were used on the experiment started during the spring of 2010. Steers were housed at the University of Nebraska-Lincoln Agriculture Research and Development Center (ARDC) research site located near Mead, NE.

***Experimental design and experimental treatments***

Two hundred and thirty-six yearling crossbred steers (BW = 429 $\pm$ 0.6 kg) were used to determine efficiency of the 2 different adaptation strategies on feedlot performance and carcass characteristics. A randomized complete block design was used with 4 blocks. Before the trial began, the steers were limit fed at 2% of their BW for 5 days to avoid large variation in gut fill for the 2 consecutive days. The average of BW measurements collected on 2 d was used to assign cattle to their pens on d 0. All animals were implanted with Revalor-S (Intervet, Schering-Plough Animal Health, Millsboro, DE) at the beginning of the study. The heavy block consisted of 1 replication of 30 steers, the medium-heavy block consisted of 1 replication of 30 steers, the medium-light block consisted of 2 replications of 30 steers and 2 replications of 28 steers, and the light block consisted of 2 replications of 28 steers. Steers were assigned randomly to a pen within block, and pens were assigned randomly to 1 of the 2 treatments (8 pens/treatment; 14 or 15 steers/pen).

The treatments consisted of decreasing concentrations of ethanol coproducts (COPRODUCT) in the diet throughout the 24-d adaptation period compared with decreasing concentrations of forage (CON) and increasing concentrations of corn in both cases. The COPRODUCT steers were fed decreasing levels of the MDGS and WCGF

combination (87.5 to 35%), whereas CON animals were fed the traditional grain adaptation diets with decreasing forage from 45 to 7.5%. Four adaptation diets (Table 3) were used to increase corn with diets fed 5, 5, 7, and 7 d, respectively. In both adaptation schemes, dry-rolled corn increased. The common finishing diet was fed for 120 d after the 24-d adaptation period and consisted of 35% of the COPRODUCT combination, 52.5% DRC, 7.5% alfalfa hay, and 5% supplement. Cattle were fed once daily at 0800. All diets supplements provided 320 to 360 mg/steer of Rumensin, 90 mg/steer of Tylan, and 150 mg/steer of thiamine daily (Table 3). Diets were formulated to meet or exceed the NRC (1996) requirements for CP, Ca, K, and P. Steers were fed once daily at 0800 h. Any feed refusals were collected, weighed, sampled, and frozen at - 20°C. Composites of orts by pen were dried to calculate DMI. Feed delivery was done with the use of a single-axle truck with Roto-Mix Model 420 (Roto-Mix, Dodge City, KS).

Final live weights collected before slaughter were mathematically shrunk 4% to account for differences in gut fill. Steers were slaughtered at a commercial packing plant (Greater Omaha Pack, Omaha, NE), and data for HCW and liver scores were collected on the day of slaughter. After a 48 h chilling period, LM area, $12^{th}$ rib fat depth, and USDA marbling scores were recorded. A calculated USDA yield grade value was determined from HCW, fat depth, LM area, and an assumed constant value for KPH of 2.5% using the equation: 2.50 + (2.5*FT, in) – (0.32*LM area, $in^2$) + (0.2*KPH, %) + (0.0038*HCW) according to Boggs and Merkel, 1993.

***Statistical analyses***

All data were analyzed using the MIXED procedures of SAS (SAS Inst. Inc., Cary,

NC) as a RCBD with pen as the experimental unit. Live performance data were analyzed not only for the entire feeding period, but also for the adaptation period separately. Different blocks were considered as random effect in the model.

## RESULTS

### *Experiment 1*.

Results for metabolic measurements during the adaptation period are presented on Table 4. During adaptation, DMI expressed as % of BW tended (P=0.09) to be greater for steers fed CON compared to CO-PRODUCT during step 1. No difference in DMI in subsequent adaptation diets was observed (P>0.20). Average ruminal pH, and minimum pH were lower ($P$<0.01) for CO-PRODUCT on step 1 and 2 compared to CON presenting results of 5.76 vs. 6.18 and 5.75 vs. 6.07, respectively for average pH and 5.48 vs. 5.80 and 5.40 vs. 5.48 respectively for minimum pH. Maximum pH was higher for the CO-PRODUCT treatment on step 1 compared to CON (6.54 vs. 6.48 respectively). No difference (P > 0.10) was observed between treatments for average ruminal pH, minimum pH or maximum pH during step 3 and 4. Average pH was lower ($P$ < 0.01) for CON on the last period when both treatments were being fed the same diet (5.61 vs. 5.80), suggesting that CO-PRODUCT adaptation treatment may have a positive effect with finishing diets containing 30% of the Synergy® (ADM, Columbus, NE) product. Area and time below pH 5.6 followed the same pattern with greater values (21.44 and 173.10 vs. 6.85 and 82.30) on the second period ($P$ < 0.03) and lower values (39.67 and 320.29 vs. 170.61 and 731.21) during the finisher period ($P$ < 0.06) for the CO-PRODUCT compared to CON. Variance of pH was significantly different on the last three periods

with higher values for animals fed the CON diets. Both adaptation methods resulted in average ruminal pH (>5.6).

Concentrations of $H_2S$ observed were always lower than 36μmol/L gas with the CO-PRODUCT treatment group being less than the CON group. Statistical difference ($P > 0.15$) was observed for DM digestibility between treatments for step 1 with higher values for the CO-PRODUCT treatment, and no difference was observed during the finishing diet. A three-way interaction was observed for the *in situ* DMD for type of feed (alfalfa and corn bran), time (24 and 32 hours) and whether incubated in CON or CO-PRODUCT steers. The NDF digestibility was measured with the objective of determine if treatments would influence in fiber digestibility and consequentially total DM digestibility. One time point was chosen (32 hours) to represent the trends observed for NDF digestibility and it is presented in Figure 1 and Figure 2. Results for metabolic measurements during the finishing diet period are presented in Table 5.

***Experiment 2***.

Results for measurements during the adaptation period are presented in Table 6, whereas results once the animals were fed the finishing diet are shown in Table 7. The DMI expressed as % of BW was greater for steers fed CON than for those fed COPRODUCT during step 3, but it did not differ during other periods ($P > 0.14$). Average, minimum, and maximum pH did not differ ($P > 0.10$) during the various steps of the adaptation period. Average pH differed ($P < 0.03$)only during the finishing period, with greater values for COPRODUCT (6.14 vs. 5.91). Moreover, minimum and maximum pH were greater ($P < 0.05$) for calves fed the COPRODUCT diet. The

COPRODUCT treatment resulted in a non-significant ($P < 0.27$) increase in DMD compared with CON treatment (68.6 vs. 57.6) during step 1.

***Experiment 3.***

Performance results during the adaptation period of Exp. 3 are summarized in Table 8. Data were collected on d 34 and the adaptation period consisted of 24 d. The DMI differed ($P < 0.01$), reflecting greater values for the CON treatment than for the COPRODUCT treatment (11.3 vs. 10.9 kg respectively). For ADG, no difference was observed ($P = 0.28$), resulting in a lower G:F ($P = 0.04$) for steers fed the COPRODUCT diets compared with CON (0.177 vs. 0.164, respectively)). Thus, steers fed the COPRODUCT diet were more efficient than animals receiving greater amounts of forage in the diet during the first month of the feeding period.

Live and carcass-adjusted live performance results are shown in Table 9. Initial BW was almost identical between both treatments, and animals started on the first step of the adaptation averaging 429 kg. Average live final BW (shrunk 4%) was not different ($P = 0.63$) at the end of the feeding period, with values of 677 kg for the CON and 679 kg for the COPRODUCT treatments. Adjusted-carcass final BW was also did not differ between treatments ($P = 0.31$).

DMI was not different after the adaptation period (P=0.20). Efficiency traits were also not statistically significant with live ADG presenting P-value of 0.57 and carcass adjusted ADG presenting P-value of 0.35. Results for G:F in a live basis followed the same pattern of ADG and had P-value of 0.15 and for carcass adjusted G:F the P-value was 0.84.

The only difference ($P = 0.04$) detected for carcass characteristics (Table 10) was calculated dressing percent (HCW/average final BW shrunk 4%) with values of 62.2 vs. 61.7 for CON and COPRODUCT treatments, respectively. All other carcass measurements did not differ between treatments. For HCW, 12th rib fat, marbling score, LM area, and USDA calculated yield grade, *P*-values for treatment were 0.35, 0.79, 0.17, 0.86 and 0.66, respectively.

Previous research reported several results for adaptation using COPRODUCTs (e.g., Krehbiel et al., 1995; Huls et al., 2009; Rolfe et al., 2010; Sarturi et al., 2011); however, all these studies investigated a single coproduct, whereas we evaluated a combination of WCGF and distillers grains with solubles. Ham et al. (1995) reported NE values for WCGF as 94 to 100% compared with DRC with high amounts of NDF and low amounts of starch, and Luebbe et al. (2008) observed greater ADG for yearling steers fed 15 and 30% MDGS substituted corn compared with a control corn-based diet; calculated feeding values of 139 and 116%, respectively, were reported relative to DRC.

Krehbiel et al. (1995) studied effects of utilization of WCGF in adapting cattle to high-concentrate diets and reported that feeding high levels of WCGF during adaptation is a viable alternative to decrease acidosis and replace dietary forage during this initial phase. Cattle fed a blend of 50% DRC:50% WCGF had a lower average ruminal pH than steers fed 100% DRC. Huls et al. (2009) conducted a metabolism trial using WCGF (Sweet Bran) at 87.5% of the dietary DM decreasing to 35% in the finishing diet, with DRC increasing to 52.5% of the diet throughout 4 different steps of adaptation, vs. the control diet consisting of 45% of alfalfa hay decreasing to 7.5% and DRC increasing

from 15% to 52.5% of the dietary DM. Results indicated lower average ruminal pH values ($P < 0.05$) for the WCGF treatment vs. control, with pH decreasing from 6.0 to 5.79 for the WCGF treatment and from 6.59 to 6.12 for the control. In addition, time and area below 5.6 were greater for the WCGF treatment. Animals fed WCGF diets had greater in situ DM digestibility ($P < 0.01$) during the 2 last periods of adaptation and the finishing diet period. Steers fed WCGF during adaptation also had greater DMI than CON steers ($P < 0.01$), which agrees with the findings of Krehbiel et al. (1995). A second study reported by Huls et al. (2009) was a feedlot experiment using 80% of WCGF (Sweet Bran) during step 1 of the adaptation period, decreasing to 35% of the DM in the finishing diet. Results indicated greater ADG and G:F for cattle fed Sweet Bran and also greater live final BW and HCW, suggesting a performance advantage for animals fed wet corn gluten feed throughout the entire feeding period compared with the traditional adaptation methods commonly used among feedlots. Huls et al. (2009) also concluded steers fed Sweet Bran were more profitable than steers fed the control diet and that utilization of Sweet Bran is a viable alternative to adapt cattle to finishing diets and prevent acidosis.

Rolfe et al. (2010) conducted a metabolism trial following the same treatment structure used by Huls et al. (2009) and fed WDGS at 87.5% of the DM of the diet, decreasing to 35% in the finishing diet, with increasing DRC up to 52.5% throughout 4 steps in adaptation period compared with a control diet consisting of 45% of alfalfa hay decreasing to 7.5% of the finishing diet throughout the adaptation period. In contrast to the results of Huls et al. (2009), steers fed WDGS had lower DMI during adaptation but

not during the finishing period compared with steers fed the control diet. In addition, steers fed WDGS had lower ruminal pH than control animals; however, during the finishing period no difference was noted in pH. Rolfe et al. (2010) measured $H_2S$ and concluded that concentrations observed during trial were not harmful for the animals, with a difference found only during the second period of the adaptation, at which time $H_2S$ concentrations were greater for animals receiving WDGS. Therefore, WDGS was considered as a viable product for adapting cattle to high-concentrate diets, but results were not as positive as results for WCGF.

To compare the 2 COPRODUCT treatments for use in adaptation strategies, Sarturi et al. (2011) conducted a metabolism trial in which both WCGF and WDGS were fed at decreasing concentrations (87.5 to 35% of DM). The WCGF treatment resulted in greater DMI than WDGS for cattle during steps 1, 2, and 3, and the average ruminal pH was less for WDGS that for WCGF during steps 2 and 3. No differences in $H_2S$ between treatments were observed. Both WCGF and WDGS adaptation methods were considered safe for in terms of measurements of ruminal pH, DMI, and $H_2S$, which agrees with previous studies reported by Huls et al. (2009) and Rolfe et al. (2010).

Results from our 3 studies are somewhat intermediate to the results of previous studies. For steers fed the combination of MDGS and WCGF compared with traditional roughage adaptation diets, DMI was not significantly different, whereas average pH results were greater than the values presented by Rolfe et al. (2010) using only WDGS, and less than the values presented by Krehbiel et al. (1995) and Huls et al. (2009) using only WCGF. In situ DM digestibility was less for the steers fed the

COPRODUCT treatment during adaptation, but during the period when a common finishing diet was fed, results were similar between treatments. No difference in feedlot performance was observed in present study. Overall, results suggest that decreasing inclusion of a combination of distillers grains and gluten feed was as effective as the traditional method using forage for adapting feedlot cattle to high-concentrate diets. Further research to determine viability of the method may be necessary. Utilization of ethanol coproducts during the adaptation diet might also help decrease management challenges associated with use of traditional forages, such as handling, hauling, transportation, etc.

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**Table 1. Adaptation and finishing diets using a combination of WCGF and MDGS compared to forage during the adaptation period for Exp 1 and 2.**

| Days fed: | 1 to 9 | 10 to 16 | 17 to 23 | 24 to 30 | 31 to 39 |
|---|---|---|---|---|---|
| Adaptation: | Step 1 | Step 2 | Step 3 | Step 4 | FINISHER |
| **CONTROL** | | | | | |
| DRC[1] | 20 | 30 | 40 | 50 | 57.5 |
| Alfalfa | 45 | 35 | 25 | 15 | 7.5 |
| MDGS[2] | 18 | 18 | 18 | 18 | 18 |
| WCGF[3] | 12 | 12 | 12 | 12 | 12 |
| Supplement[4] | 5 | 5 | 5 | 5 | 5 |
| Fine ground corn | 4.067 | 3.720 | 3.373 | 2.852 | 3.025 |
| Limestone | 0.393 | 0.740 | 1.087 | 1.608 | 1.435 |
| Salt | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Trace mineral premix | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| Vitamin premix | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 |
| Monensin 90 premix | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Tylosin 40 premix | 0.01125 | 0.01125 | 0.01125 | 0.01125 | 0.01125 |
| Thiamine 40 premix | 0.01875 | 0.01875 | 0.01875 | 0.01875 | 0.01875 |
| Tallow | 0.125 | 0.125 | 0.125 | 0.125 | 0.125 |
| **CO-PRODUCT** | | | | | |
| DRC[1] | 0 | 14.4 | 28.8 | 43.2 | 57.5 |
| Alfalfa | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 |
| MDGS[2] | 52.5 | 43.9 | 35.2 | 26.6 | 18 |
| WCGF[3] | 35 | 29.2 | 23.5 | 17.7 | 12 |
| Supplement[4] | 5 | 5 | 5 | 5 | 5 |
| Fine ground corn | 2.331 | 2.6782 | 3.0254 | 2.8518 | 3.025 |
| Limestone | 2.129 | 1.7818 | 1.4346 | 1.6082 | 1.435 |
| Salt | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Trace mineral premix | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| Vitamin premix | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 |
| Monensin 90 premix | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Tylosin 40 premix | 0.01125 | 0.01125 | 0.01125 | 0.01125 | 0.01125 |
| Thiamine 40 premix | 0.01875 | 0.01875 | 0.01875 | 0.01875 | 0.01875 |
| Tallow | 0.125 | 0.125 | 0.125 | 0.125 | 0.125 |

[1]DRC: Dry rolled corn

[2]MDGS: Modified distillers grains with solubles

[3]WCGF: Wet corn gluten feed

[4]Supplement formulated to provide 90 mg/head/day of tylosin, 360 mg/head/day of monensin and 150 mg/head/day of thiamine.

**Table 2. Analyzed nutrient analysis for feeds fed, % DM.**

| | Diet ingredients[1] | | | |
|---|---|---|---|---|
| *Analysis* | MDGS | WCGF | DRC | ALFALFA |
| DM | 62.5 | 44.1 | 86.4 | 87.8 |
| CP | 32.5 | 21.3 | 7.9 | 18.6 |
| Ether Extract | 11.3 | 3.3 | 3.9 | 0.9 |
| NDF | 38.6 | 54.7 | 10.4 | 63.9 |
| Sulfur | 0.81 | 0.48 | 0.11 | 0.29 |
| Ash | 0.06 | 0.04 | 0.01 | 0.09 |

[1]MDGS: Modified distillers grains with solubles
WCGF: Wet corn gluten feed
DRC: Dry rolled corn

**Table 3. Adaptation and finishing diets using a combination of WCGF and MDGS (ADM Golden Synergy) compared to forage during the adaptation period for Exp 3.**

| | Adaptation | | | | |
|---|---|---|---|---|---|
| Ingredients, % DM | STEP 1 | STEP 2 | STEP 3 | STEP 4 | Finishing |
| Control | | | | | |
| ADM Golden Synergy | 35 | 35 | 35 | 35 | 35 |
| Dry rolled corn | 20 | 30 | 40 | 50 | 52.5 |
| Alfalfa | 45 | 35 | 25 | 15 | 7.5 |
| Supplement[1] | 5 | 5 | 5 | 5 | 5 |
| Fine ground corn | 2.585 | 2.585 | 2.585 | 2.585 | 2.585 |
| Limestone | 1.876 | 1.876 | 1.876 | 1.876 | 1.876 |
| Salt | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Trace mineral premix | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| Vitamin premix | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 |
| Monensin 90 premix | 0.01875 | 0.01875 | 0.01875 | 0.01875 | 0.01875 |
| Tylosin 40 premix | 0.01125 | 0.01125 | 0.01125 | 0.01125 | 0.01125 |
| Thiamine 40 premix | 0.01875 | 0.01875 | 0.01875 | 0.01875 | 0.01875 |
| Tallow | 0.125 | 0.125 | 0.125 | 0.125 | 0.125 |
| CO-PRODUCT | | | | | |
| ADM Golden Synergy | 87.5 | 74.375 | 61.25 | 48.125 | 35 |
| Dry rolled corn | 0 | 13.125 | 26.25 | 39.375 | 52.5 |
| Alfalfa | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 |
| Supplement[1] | 5 | 5 | 5 | 5 | 5 |
| Fine ground corn | 2.585 | 2.585 | 2.585 | 2.585 | 2.585 |
| Limestone | 1.876 | 1.876 | 1.876 | 1.876 | 1.876 |
| Salt | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Trace mineral premix | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| Vitamin premix | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 |
| Monensin 90 premix | 0.01875 | 0.01875 | 0.01875 | 0.01875 | 0.01875 |
| Tylosin 40 premix | 0.01125 | 0.01125 | 0.01125 | 0.01125 | 0.01125 |
| Thiamine 40 premix | 0.01875 | 0.01875 | 0.01875 | 0.01875 | 0.01875 |
| Tallow | 0.125 | 0.125 | 0.125 | 0.125 | 0.125 |

[1]Supplement formulated to provide 90 mg/head/day of tylosin, 360 mg/head/day of monensin and 150 mg/head/day of thiamine.

**Table 4. Exp.1 results for DMI, ruminal pH, $H_2S$ production, and total tract DM digestibility for the adaptation period when comparing forage and co-product diets to adapt cattle to a high grain finishing diet.**

| | Step 1 | | | Step 2 | | | Step 3 | | | Step 4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Control | Co-product | P-value | Control | Co-product | P-value | Control | Co-product | P-value | Control | Co-product | P-value |
| DMI, % BW | 2.32 | 2.05 | 0.09 | 2.72 | 2.37 | 0.18 | 2.93 | 2.67 | 0.34 | 2.98 | 2.79 | 0.37 |
| Average pH | 6.18 | 5.76 | <0.01 | 6.07 | 5.75 | <0.01 | 5.89 | 5.84 | 0.44 | 5.62 | 5.67 | 0.75 |
| Maximum pH | 6.38 | 6.54 | <0.01 | 6.66 | 6.34 | <0.01 | 6.52 | 6.41 | 0.11 | 6.27 | 6.36 | 0.63 |
| Minimum pH | 5.80 | 5.48 | <0.01 | 5.48 | 5.4 | 0.24 | 5.31 | 5.36 | 0.53 | 5.1 | 5.26 | 0.36 |
| pH variance | 0.03 | 0.05 | 0.23 | 0.06 | 0.04 | 0.17 | 0.07 | 0.04 | 0.02 | 0.07 | 0.05 | 0.04 |
| Area <5.6 | 6.85 | 21.44 | 0.29 | 6.7 | 40.3 | 0.03 | 51.54 | 48.8 | 0.92 | 191.64 | 149.04 | 0.65 |
| Time <5.6, min. | 82.3 | 173.1 | 0.38 | 36.55 | 411.03 | 0.02 | 307.29 | 318.94 | 0.93 | 740.43 | 688.74 | 0.81 |
| $H_2S$, µmol/L | 24.81 | 13.94 | 0.20 | 24.49 | 6.11 | <0.01 | 31.12 | 23.51 | 0.52 | 36.36 | 24.05 | 0.35 |
| DM digestibility, % | 57.69 | 67.96 | 0.05 | | | | | | | | | |

**Table 5. Exp. 1 results for DMI, ruminal pH, $H_2S$ production and DM digestibility during finishing diet.**

| Treatments | Control | Co-product | SEM | P-value |
|---|---|---|---|---|
| DMI, % BW | 2.85 | 2.80 | 0.11 | 0.74 |
| Average pH | 5.60 | 5.80 | 0.19 | <0.01 |
| Maximum pH | 6.23 | 6.41 | 0.09 | 0.13 |
| Minimum pH | 5.36 | 5.14 | 0.06 | 0.02 |
| pH variance | 0.06 | 0.04 | 0.006 | 0.02 |
| Area <5.6[1] | 170.61 | 39.67 | 50.49 | 0.06 |
| Time <5.6, min. | 731.21 | 320.29 | 149.90 | 0.05 |
| Area <5.3[1] | 26.61 | 0.18 | 12.68 | 0.10 |
| Time <5.3, min. | 242.47 | 8.57 | 97.67 | 0.07 |
| $H_2S$, μmol/L | 22.44 | 22.14 | 12.79 | 0.98 |
| DMD, % | 67.89 | 70.68 | 2.77 | 0.51 |

**Table 6. Exp.2 results for DMI, ruminal pH, $H_2S$ production, and total tract DM digestibility for the adaptation period when comparing forage and co-product diets to adapt cattle to a high grain finishing diet.**

| | Step 1 | | | Step 2 | | | Step 3 | | | Step 4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Control | Co-product | P-value | Control | Co-product | P-value | Control | Co-product | P-value | Control | Co-product | P-value |
| DMI, % BW | 2.33 | 1.95 | 0.14 | 2.68 | 2.76 | 0.64 | 2.93 | 2.71 | 0.08 | 3.15 | 2.8 | 0.32 |
| Average pH | 6.1 | 6.61 | 0.29 | 6.22 | 6.15 | 0.59 | 6.23 | 6.13 | 0.33 | 6.06 | 5.95 | 0.31 |
| Maximum pH | 6.75 | 6.75 | 0.99 | 6.88 | 6.65 | 0.33 | 6.92 | 6.5 | 0.16 | 6.87 | 6.46 | 0.18 |
| Minimum pH | 5.53 | 6.31 | 0.19 | 5.17 | 5.27 | 0.88 | 5.61 | 5.78 | 0.13 | 5.54 | 5.53 | 0.95 |
| pH variance | 0.24 | 0.18 | 0.15 | 0.27 | 0.21 | 0.25 | 0.29 | 0.15 | 0.07 | 0.27 | 0.19 | 0.22 |
| Area <5.6 | 2.63 | 5.33 | 0.49 | 7.23 | 4.77 | 0.71 | 2 | 0 | 0.15 | 3.54 | 4.91 | 0.77 |
| Time <5.6, min. | 38.29 | 108.84 | 0.28 | 9.5 | 6.53 | 0.73 | 28.16 | 0 | 0.14 | 52.39 | 10.22 | 0.26 |
| DM digestibility, % | 57.58 | 68.64 | 0.27 | | | | | | | | | |

**Table 7. Exp.2 results for DMI, ruminal pH, $H_2S$ production and DM digestibility during finishing diet.**

| Treatments | Control | Co-product | SEM | P-value |
|---|---|---|---|---|
| DMI, % BW | 3.17 | 3.08 | 0.21 | 0.66 |
| Average pH | 5.91 | 6.14 | 0.06 | 0.03 |
| Maximum pH | 6.36 | 6.88 | 0.05 | <0.01 |
| Minimum pH | 5.47 | 5.62 | 0.05 | 0.05 |
| pH variance | 0.18 | 0.26 | 0.02 | 0.03 |
| Area <5.6 | 6.88 | 0.96 | 3.32 | 0.17 |
| Time <5.6, min. | 92.11 | 19.97 | 43.87 | 0.20 |
| DMD, % | 56.64 | 73.07 | 4.03 | 0.02 |

**Table 8. Growth performance results for exp. 3 during first 35 days.**

| | Treatments[1] | | | |
|---|---|---|---|---|
| | CON | CO-PRODUCT | SEM | P-value |
| *Live Performance* | | | | |
| Initial BW, kg | 429 | 429 | 0.59 | 1 |
| Adaptation BW, kg | 494 | 497 | 2.3 | 0.22 |
| DMI, kg/d | 11.26 | 10.86 | 0.12 | <0.01 |
| ADG, kg | 1.84 | 1.92 | 0.08 | 0.28 |
| G:F | 0.164 | 0.177 | 0.006 | 0.04 |

[1]CON: Control treatment with traditional adaptation using roughage.
CO-PRODUCT: Treatment utilizing a combination of modified distillers grains with solubles and wet corn gluten feed.

**Table 9. Growth performance results for exp. 3**

| | Treatments[1] | | | |
|---|---|---|---|---|
| | CON | CO-PRODUCT | SEM | P-value |
| *Live Performance* | | | | |
| Initial BW, kg | 429 | 429 | 0.59 | 1 |
| BW after Adaptation, kg | 494 | 497 | 2.3 | 0.22 |
| Live Final BW, kg | 677 | 679 | 3.24 | 0.63 |
| DMI, kg/d | 11.45 | 11.31 | 0.11 | 0.2 |
| ADG, kg | 1.72 | 1.73 | 0.02 | 0.57 |
| G:F | 0.151 | 0.153 | 0.001 | 0.15 |
| *Carcass Adjusted Performance* | | | | |
| Final BW, kg | 669 | 664 | 4.07 | 0.31 |
| ADG, kg | 1.66 | 1.63 | 0.03 | 0.35 |
| G:F | 0.145 | 0.145 | 0.002 | 0.84 |

[1]CON: Control treatment with traditional adaptation using roughage.
CO-PRODUCT: Treatment utilizing a combination of modified distillers grains with solubles and wet corn gluten feed.

**Table 10. Carcass characteristics results for exp. 3.**

| | Treatments[1] | | | |
|---|---|---|---|---|
| | CON | CO-PRODUCT | SEM | P-value |
| *Carcass Characteristics* | | | | |
| HCW, kg | 421 | 419 | 2.57 | 0.35 |
| Dressing, %[2] | 62.2 | 61.7 | 0.23 | 0.04 |
| 12$^{th}$ rib fat, cm | 1.63 | 1.62 | 0.02 | 0.79 |
| Marbling score[3] | 660 | 636 | 16.3 | 0.17 |
| LM area, cm$^2$ | 88.06 | 87.94 | 0.66 | 0.86 |
| USDA yield grade[4] | 3.76 | 3.73 | 0.08 | 0.66 |

[1]CON: Control treatment with traditional adaptation using roughage.
CO-PRODUCT: Treatment utilizing a combination of modified distillers grains with solubles and wet corn gluten feed.
[2]Dressing percentage = carcass weight / average live weight (4% shrink).
[3]USDA marbling score where 450=slight50, 500=small0, and 550=small50
[4]USDA calculated yield grade = 2.50 + (2.5*FT, in) – (0.32*LM area, in$^2$) + (0.2*KPH, %) + (0.0038*HCW).

**Figure 1. The *in situ* digestibility during the 4 adaptation steps and finishing diet for forage and byproduct treatments for alfalfa NDF digestibility (incubation time 32 hours).**

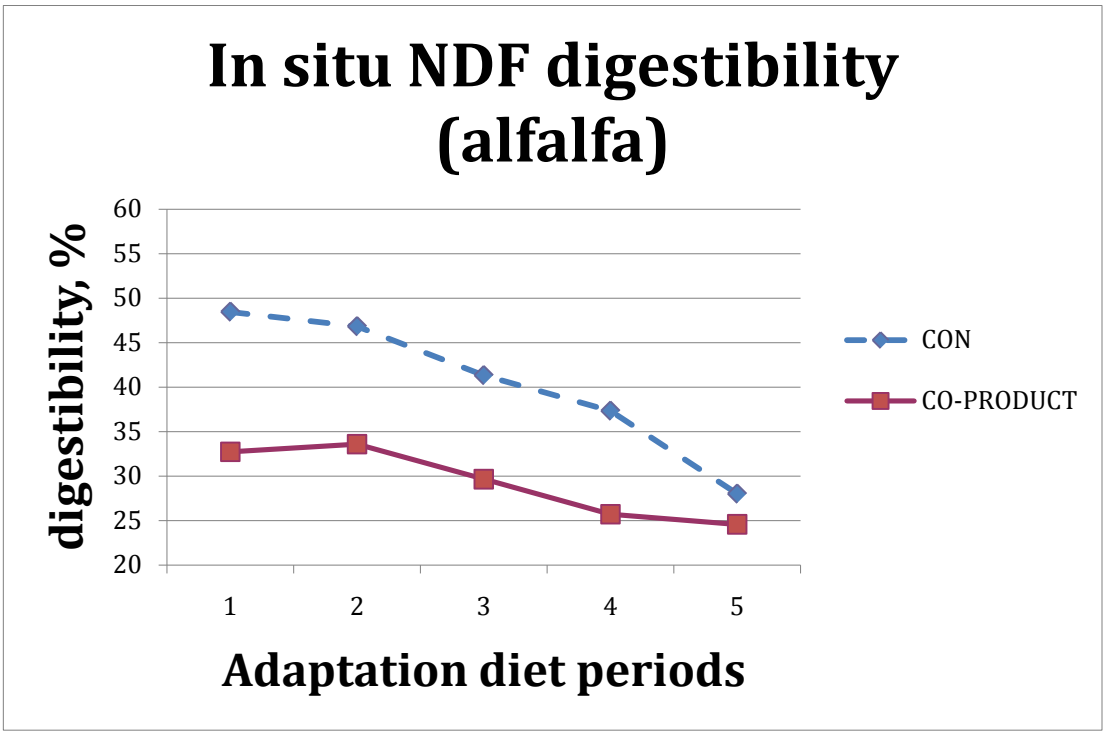
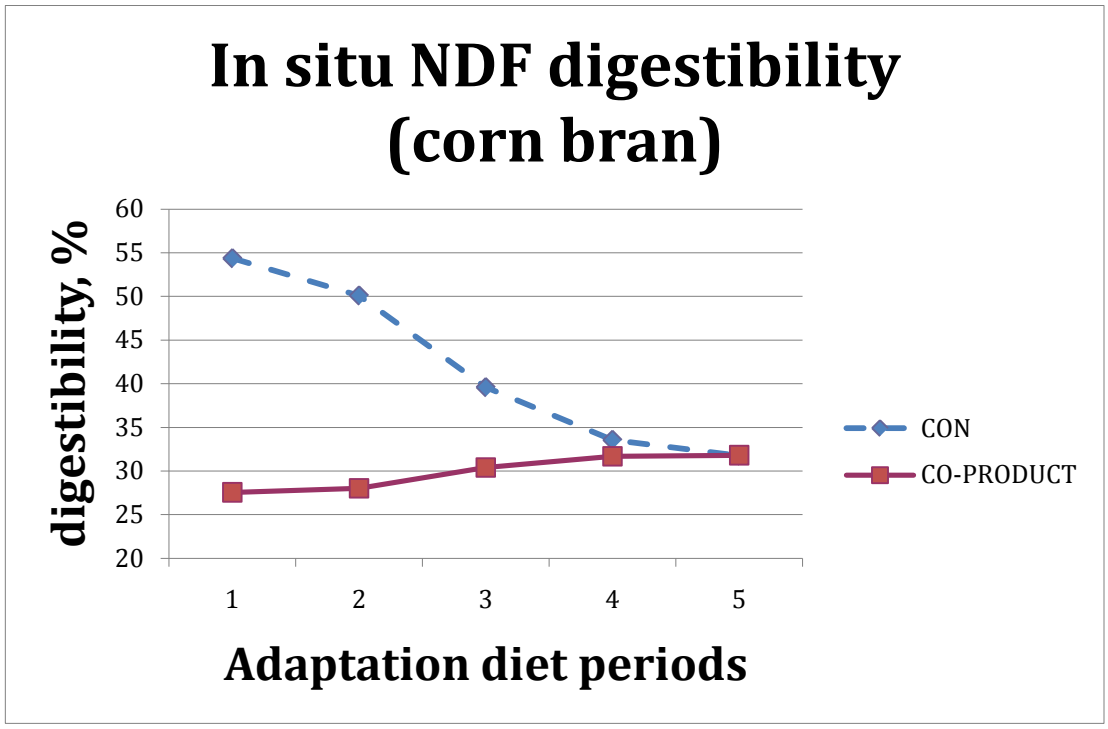


**Figure 2. The *in situ* digestibility during the 4 adaptation steps and finishing diet for forage and byproduct treatments for corn bran NDF digestibility (incubation time 32 hours).**



# CHAPTER IV

**Effects of intermittent feeding of ractopamine hydrochloride on growth performance and carcass characteristics of feedlot steers**

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## ABSTRACT

Three hundred and twenty crossbred steers (initial BW = 480 kg $\pm$ 12 kg) were utilized in a finishing feedlot study to evaluate the effects of intermittent versus continuously feeding of ractopamine hydrochloride (RAC) on performance and carcass characteristics. Steers were blocked by BW and allotted to one of the four treatments (8 pens/treatment and 10 steers/pen). Live BW and carcass traits of steer calves were evaluated after by feeding 200mg daily of RAC for 35 days. The negative control (NONE) consisted of 63 days on the same diet without RAC, whereas the positive control (CONTIN) consisted of RAC supplemented daily during the last 35 days prior to harvest. The 4-day intermittent treatment (4-dINT) consisted of feeding RAC for 7 days, followed by 4 days of no RAC, while the 7-day intermittent treatment (7-dINT) consisted of 7 d on RAC, followed by 7 days off. In both the 4-dINT and 7-dINT treatments, cattle also received RAC for a total of 35 days. There were no differences due to delivery feeding pattern ($P > 0.05$) in

feedlot performance or carcass characteristics. Although, feeding RAC increased ADG ($P < 0.01$), DMI ($P = 0.05$), and live BW ($P = 0.04$) compared to NONE and a tendency for increased G:F was also observed ($P = 0.09$). No effect was observed for carcass characteristics among treatments ($P > 0.05$), but a tendency for increased REA was observed for treatments receiving RAC. Feeding 200 mg per steer daily of RAC for a total of 35 days in either 4-day or 7-day intermittent patterns was as effective, but not more so, as continuous feeding for a 35-day period.

**Key Words:** β- adrenergic receptors agonists, beef cattle, carcass characteristics, performance, ractopamine

## INTRODUCTION

Effects of metabolic growth modifier compounds have been extensively researched in livestock animals in the last two decades. Phenethanolamines, a group of exogenous compounds with similar chemical structures found in dopamine, epinephrine and norepinephrine also known as β- adrenergic agonists (β-AA) are one of them (Bell et al., 1998). Ractopamine hydrochloride (RAC) is a repartitioning agent that improves growth performance increasing protein accretion and gain efficiency, and decreasing adipose tissue deposition (e.g. Ricks et al., 1984; Watkins, 1990; Xiao et al, 1999). Ractopamine hydrochloride was approved for continuous feeding to feedlot cattle during the last 28 to 42 days prior to harvest at a dose ranging from 70 to 430 mg per steer daily or 9.1 to 27.3 g/ton of DM in 2003 by the USDA. Since then many data with cattle and swine have been published and results agree that feeding 200 mg of RAC from 28 to 42 does not affect negatively adipose tissue deposition (e.g., Abney et al., 2007; Greenquist

et al., 2007). Continuous feeding of RAC for 42, 35 and 28 days prior to harvest at doses up to 200 mg per steer increased live BW from 2 to 9 kg compared with a control diet without RAC, and improved ADG an average of 0.25 kg/day in feedlot steers (Abney et al., 2007). In addition, LM areas were also larger or tended to be larger for animals treated with RAC, with no effect on back fat thickness (Crawford et al., 2006; Abney et al., 2007; Greenquist et al., 2007).

According to past research, β-AA results commonly present a decrease in growth response after a certain period of time by the animals and that is due to the phenomenon of desensitization of the $\beta$-adrenergic receptor caused by a long continuous exposure to the β-AA (e.g., Hausdorff et al., 1990; Sainz et al., 1993; Byrem et al., 1997; Abney et al., 2007). Studies with swine indicate that intermittent use of RAC may help diminish this negative effect in performance because of the resting time given to the receptors. Some differences in traits observed in some studies were increase in ADG, G:F, and BW (e.g., Neill et al., 2005). Therefore, the objective of the present study was to evaluate the effects of intermittent use of RAC on growth and carcass characteristics of feedlot steers.

# MATERIALS AND METHODS

### *Location, animals and management*

In this experiment, 320 crossbred steers predominately black hided British breed influence were purchased in the fall of 2008 as weaned calves with approximately 7-8 months of age. Steers were transported to the University of Nebraska-Lincoln Agriculture Research and Development Center (ARDC) research site located near Mead, NE. The

area presents low average temperatures during the winter (-0.3°C in January) and high average temperatures during the summer (30.9°C in July). The annual precipitation in the area range around 700mm and the majority of the rainfall occurs between April and September (NCDC, 2010). Animals were individually indentified at arrival, vaccinated and treated against parasites if necessary, and then revaccinated later on. Animals were fed a forage-based diet composed by hay and wet corn gluten feed (Sweet Bran; Cargill Inc., Blair, NE).

Animals were weighed and implanted with Component TE-IS® (Vetlife Ivy Animal Health, Overland Park, KS) at first and reimplanted with Component TE-S® (Vetlife Ivy Animal Health, Overland Park, KS) 98 days prior harvest. After three consecutive days of weight collection, animals were assigned to two blocks based on reimplant BW.

***Experimental design and experimental treatments***

Animals (n=320) were utilized in a randomized complete block design finishing experiment with two blocks. The heavy block consisted of 1 replication of 40 steers and the light block consisted of 7 replications of 280 steers. Steers were assigned randomly to a pen within block and pens assigned randomly to 1 of the 4 treatments (8 pens/treatment; 10 steers/pen). The treatments consisted of no delivery of RAC (NONE), continuously feeding of RAC throughout the last 35 days prior to harvest (CONTIN), intermittent 7 day feeding RAC followed by 4 day of withdrawal (4-dINT) and intermittent 7 days feeding RAC followed by 7 days of withdrawal (7-dINT). The three treatments with RAC

resulted in a total of 35 d of feeding RAC but on different days. Steers were managed during the pre-trial phase (102 days) in the actual experiment pens after being assigned within a block (4 pens for the heavy block and 28 pens for the light block). Three animals were removed from 3 different pens prior to RAC feeding due to death or health reasons. Before the start of the trial, each steer was weighed on two consecutive days after feed restriction (decrease of 1 kg/day of DM during 3 days). Pens of animals were weighed weekly, with a 4% shrink factor applied to the BW, throughout the 63 days of the RAC treatment period and prior to harvest.

Steers were fed once per day at approximately 0830 hr and the RAC supplement was top dressed in a supplement at a rate of 230 g per steer to ensure that steers received the amount of 200mg of RAC per day. The carrier used was fine ground corn. Steers received 230 g of fine ground corn when not on RAC or for the negative control treatment. Diets were formulated to meet or exceed NRC (1996) requirements, for metabolizable protein, Ca, P and K. High-moisture corn (HMC) was fed at 50% of diet DM, wet corn gluten feed (WCGF) at 40% of DM and ground wheat straw at 5% of DM (Table.1). Diets were prepared by loading the HMC, WCGF, ground wheat straw and then by adding dry supplement in the mixer/delivery box (Roto-Mix® model 420, Roto-Mix®, Dodge City, Kansas). Monensin (Rumensin®, Elanco Animal Health, Greenfield, IN) and tylosin (Tylan®, Elanco Animal Health, greenfield, IN) were fed to all steers with consumptions of 348 and 90 mg/head/daily respectively. Feeds and feeding procedures remained the same throughout the pre-trial and trial phases, except for the use of the top dressing with or without RAC that occurred only during the last 63 days prior

to harvest.

***Data collection***

Feed samples were collected from each load and each supplement (with or without RAC) every other week, during the mixer discharge in the beginning, middle and end of each load. RAC supplements were sampled from supplement bags. Samples were processed and analyzed for DM content, CP, Ca, P, K, and ether extract, being 66.3, 14.3, 4.3, 0.66, 0.54, and 0.74 (in % of DM) respectively.

All steers were harvested on the same day after 165 days on feed, and 63 days of RAC treatment period. At harvest, HCW were collected and after approximately a 48-hr chill, LM area and fat thickness were measured. Bone score, lean score and KPH were subjectively assigned by a UNL research technician, and marbling score was assigned by a USDA grader. Yield grade was calculated using the equation (YG= 2.50 + (2.5*FT, in) – (0.32*LM area, $in^2$) + (0.2*KPH, %) + (0.0038*HCW, lb)). Growth performance was evaluated on a 4% shrunk weight basis, across and within RAC treatments period.

***Statistical analyses***

Performance and carcass data from the randomized complete block design experiment were analyzed using a mixed model analysis, MIXED procedure of SAS (Version 9.1, SAS Inc., Cary, NC), with treatment and block included in the model as fixed variables. Pen was the experimental unit. Data were analyzed using a protected *F*-test and means separated using a bonferroni t-test when the F-test variable was significant

(i.e., alpha = 0.05).

## RESULTS AND DISCUSSION

Results for feedlot performance and carcass characteristics are presented in Table 2 and Table 3, respectively. Dry matter intake was affected ($P = 0.05$) by RAC 7-dINT treatment with steers consuming slightly more DM than all other treatments. This result does not concur with past research results and it might be due to animals with numerically higher weights than observed on the other treatments even though P-value for initial BW was 0.28 (numerically difference not enough to be detected statistically). No difference in DMI was found between NONE, CONTIN and 4-dINT in agreement with past literature reports such as P = 0.66 (Greequist et al., 2007) and P = 0.16 for linear and P = 0.36 for quadratic analysis observed in the feedlot experiment by Abney et al. (2007).

Live BW increased ($P < 0.04$) for all RAC treatments compared to NONE. RAC treatment 7-dINT was also significantly different from the CONTIN and 4-dINT with higher values for Live BW. The CONTIN was approximately 6.5 kg heavier than the NONE, the 4-dINT was 5.9 kg (no difference when compared with the CONTIN) and the 7-dINT was 15 kg heavier than the NONE, and approximately 8.6 kg heavier than the CONTIN and 4-dINT treatments. Weekly performance compared to control is presented on Figure 1 for the last 63 days prior harvest. Results for increase in live BW is in agreement with observations found in past literature. Schroeder et al., 2004 reported an increase of 7.8 kg for treatments receiving 200 mg of RAC daily, also experiments where

treatments received specifically 200 mg daily of RAC for 35 days continuously resulted in increases of 9 kg compared to control on results reported by Abney et al. (2007), 8.2 kg difference was observed by Greenquist et al. (2007).

Live ADG was also positively affected by the RAC treatments compared to NONE, providing an increase of approximately 132 g/day. Previous research also reported significative increases in live ADG. Abney et al. (2007) observed a difference of 230 g in ADG for animals receiving 200 mg of RAC during 35 days compared to control. Schroeder et al. (2004) also reported an increase of 19.6 % on ADG for animals receiving 200 mg fed per day of RAC compared to control with no RAC. Increases in live ADG were observed in other different experiments not only for the 200 mg fed for 35 but also 100 and 300 mg of RAC fed daily.

Results for live performance adjusted for carcass differed from previous literature observations where adjusted final BW, ADG and G:F were usually reported with statistical significant improvements (Schroeder et al., 2004; Abney et al., 2007). In our study, live performance on a carcass adjusted basis, treatments were not different compared to NONE ($P > 0.05$). Same pattern was observed on our carcass traits data ($P > 0.05$) except for the calculated yield grade trait that decreased for the 4-dINT treatment ($P < 0.01$) when compared to all other treatments due to differences in KPH scores assigned to the carcasses and accounted for in the calculation (USDA calculated yield grade = 2.50 + (2.5*FT, in) – (0.32*LM area, $in^2$) + (0.2*KPH, %) + (0.0038*HCW)).

Positive trends for carcass adjusted final BW, HCW and LM area (P = 0.19, P = 0.18 and P = 0.09 respectively) were observed mainly for the 7-dINT treatment when compared to the others. Gain efficiency (G:F) analyses show that steers on RAC treatments had numerically lower values than NONE. Previous works showed more significant results for live adjusted performance and carcass than the present study, Greenquist et al. (2007) observed an increase of 4.54 kg in HCW (P<0.01) and 8.18 kg on carcass adjusted final BW, also 12% improvement in G:F and additional 240 g on ADG compared to control. Abney et al. (2007) reported a difference of 6.5 kg on HCW compared to control (P=0.02) and 10.4 kg on carcass adjusted final BW, 280 g of increase in ADG adjusted for carcass and an increase of 20% in G:F after corrected for carcass. Anderson et al. (1989), Schroeder et al. (2004) and many of swine data (e.g., Watkins et al., 1990; Williams et al. 1994) also observed increases on ADG and G:F for treatments fed RAC, in addition to live and carcass weight differences.

Results from this experiment agreed with past studies indicating that 200 mg/steer daily of RAC fed increases DMI, ADG and Live BW (Laudert et al., 2005a and 2005b; Abney et al., 2007; Greenquist et al., 2007), however our hypothesis on attempt to stimulate diminished responses throughout the time expressed by the $\beta$-adrenergic receptor due to the phenomenon of desensitization described by many authors (e.g., Hausdorff et al., 1990; Sainz et al., 1993; Byrem et al., 1997; Moody et al., 2000; Johnson, 2004) was not successful.

Tendencies for a larger LM area on the positive control and better G:F on all RAC treatments were also observed following the same pattern of results found in the past,

specially on swine fed RAC where larger LM area was extensively studied in early experiments on effects of $\beta$-adrenergic agonists on growth performance and carcass merit.

Intermittent feeding of RAC did not appear to influence growth performance compared to continuous feeding, although more research is needed to understand the biological effect of different feeding strategies in the $\beta$-adrenergic agonists receptors of beef cattle.

## CONCLUSION

In conclusion, withdrawing RAC for 7 or 4 days then re-feeding when compared to continuous, had no effect in live ADG, G:F, or any carcass characteristic, however animals fed RAC had better live performance and positive trends for carcass characteristics compared to animals that did not receive the feed additive.

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**Table 1**. Diet composition and analyzed nutrient analysis for diets fed.

| Ingredient, % of DM | |
|---|---|
| High-moisture Corn | 50.0 |
| Wet Corn Gluten Feed | 40.0 |
| Ground Wheat Straw | 5.0 |
| Dry Supplement | 5.0 |
| | |
| *Analyzed Nutrient Analysis, % DM* | |
| DM | 66.3 |
| CP | 14.3 |
| Ether Extract | 4.3 |
| Calcium | 0.66 |
| Phosphorus | 0.54 |
| Potassium | 0.74 |

**Table 2**. Growth performance results for steers fed RAC in continuous vs. intermittent patterns.

| | Treatments[1] | | | | | |
|---|---|---|---|---|---|---|
| | NONE | CONTIN | 4-dINT | 7-dINT | SEM | P-value |
| *Live Performance* | | | | | | |
| Initial BW, kg | 490 | 489 | 488 | 495 | 8.7 | 0.28 |
| Live Final BW, kg | 614[a] | 621[b] | 620[b] | 629[c] | 10.7 | 0.04 |
| DMI, kg/d | 10.14[a] | 10.02[a] | 10.14[a] | 10.40[b] | 0.31 | 0.05 |
| ADG, kg | 1.98[a] | 2.09[b] | 2.10[b] | 2.13[b] | 0.09 | <0.01 |
| G:F | 0.197 | 0.211 | 0.208 | 0.207 | 0.007 | 0.09 |
| *Carcass Adjusted Performance* | | | | | | |
| FBW, kg | 612 | 617 | 614 | 623 | 11.5 | 0.19 |
| ADG, kg | 1.98 | 2.02 | 2.01 | 2.03 | 0.12 | 0.4 |
| G:F | 0.194 | 0.204 | 0.199 | 0.199 | 0.1 | 0.52 |

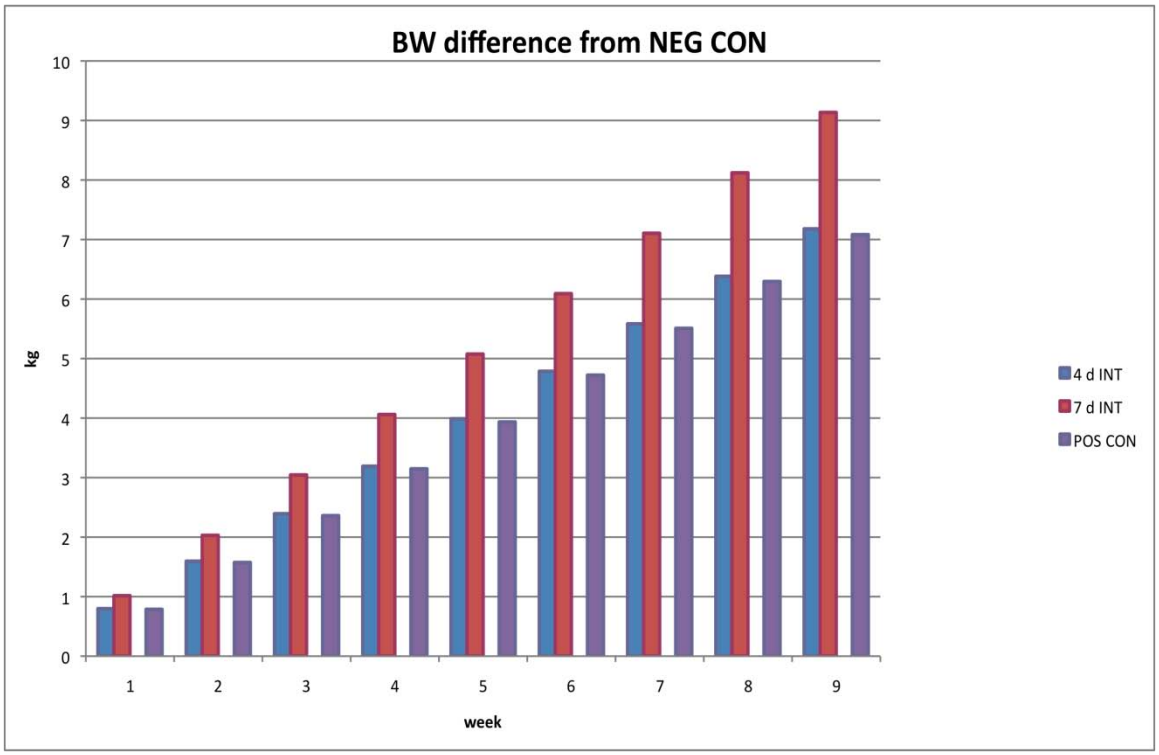
[1]NONE: treatment did not receive RAC.
CONTIN: treatment received RAC for 35 days continuously.
4-dINT: treatment received intermittent 7 day feeding RAC followed by 4 day of withdrawal.
7-dINT: treatment received intermittent 7 day feeding RAC followed by 7 day of withdrawal.

**Table 3**. Carcass characteristics results for steers fed RAC in continuous vs. intermittent patterns

| | Treatments[1] | | | | | |
|---|---|---|---|---|---|---|
| | NONE | CONTIN | 4-dINT | 7-dINT | SEM | P-value |
| *Carcass Characteristics* | | | | | | |
| HCW, kg | 386 | 388 | 387 | 392 | 7.3 | 0.18 |
| Dressing, %[a] | 62.8 | 62.5 | 62.4 | 62.4 | 0.22 | 0.25 |
| 12$^{th}$ rib fat, cm | 1.27 | 1.22 | 1.25 | 1.32 | 0.03 | 0.51 |
| Marbling score[b] | 507 | 485 | 506 | 505 | 14 | 0.37 |
| LM area, cm$^2$ | 94.2 | 97.4 | 93.5 | 94.2 | 0.2 | 0.09 |
| USDA yield grade[c] | 2.73[a] | 2.76[a] | 2.45[b] | 2.78[a] | 0.1 | <0.01 |

[1]NONE: treatment did not receive RAC.
CONTIN: treatment received RAC for 35 days continuously.
4-dINT: treatment received intermittent 7 day feeding RAC followed by 4 day of withdrawal.
7-dINT: treatment received intermittent 7 day feeding RAC followed by 7 day of withdrawal.
[a]Dressing percentage = carcass weight / average live weight (4% shrink).
[b]USDA marbling score where 450=slight50, 500=small0, and 550=small50
[c]USDA calculated yield grade = 2.50 + (2.5*FT, in) – (0.32*LM area, in$^2$) + (0.2*KPH, %) + (0.0038*HCW).

**Figure 1**. Difference in weekly live BW between ractopamine-HCL treatments and negative control (no ractopamine) during the last 63 days on feed.



# CHAPTER V

**Genetic parameters for mature cow weight and height in American Angus cattle**

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## ABSTRACT

Genetic parameters for weights and heights of mature cows were estimated from field data supplied by the American Angus Association. Analyses were executed using MTDFREML in a repeatability model for two samples of approximately 23,000 and 13,000 records of mature weight (MW) and height (MH) respectively. The four-generation pedigree files were included in the analysis and the mathematical model included a fixed effect of age, and random effects of contemporary group, permanent environment of the cow, additive genetic value of the cow and residual. Genetic trends for mature weight and height were developed considering the past 25 years. Results showed that the heritabilities of both traits are moderate-high (MW ranged between 0.44 and 0.48 and MH ranged between 0.62 and 0.65). Genetic correlations between them were positive and strong ranging between 0.80 and 0.83 and permanent environment correlations were between 0.69 and 0.73. These estimates suggest that either trait would respond favorably to selection and changing one would lead to a correlated response in the other. Genetic trend was generally for increasing MW and MH over the last 25 years with some indication of a plateau or decrease in more recent years.

**Key Words:** Beef cattle, Genetic parameters, Mature size

## INTRODUCTION

Cow weights and heights have been used to estimate lifetime growth curves, influence of body size on efficiency, maintenance requirements, cow-calf profitability, reproduction, and cull cow value (e.g., DeNise and Brinks, 1985; Johnson et al., 1990; Jenkins et al., 1991; McMorris and Wilton, 1986; Kress et al., 1969; Whitman et al., 1975). Mature size may potentially impact the profitability of beef enterprises and thus should be considered in selection programs, and evidence for that could be described as differences in maintenance requirements (energy) by the cow herd (Klosterman et al., 1968; Owens 1993). Previous direct heritability estimates have been generally moderate to high using various models ranging between 0.39 and 0.51 for mature weight in Angus cows and from 0.68 to 0.83 for mature height (e.g., Northcutt and Wilson, 1993; Bullock et al., 1993; Johnston et al., 1996; Arango et al., 2002). Researchers have reported high and positive correlations between mature weight and mature height and also mature size and growth rates during the preweaning period (e.g. McMorris and Wilton, 1986; Northcutt and Wilson, 1993; Arango et al., 2002). In order to implement genetic evaluations for these mature traits, it is important to have accurate estimates of genetic parameters. These results may benefit producers when selecting for an optimal cow size given their production environment, taking in consideration cost of beef cow maintenance, and profitability of calves from different expected birth and weaning weights. The objective of the current study was to estimate genetic parameters and (co) variance components for mature weight and mature height of Angus cows using a

repeatability model and to estimate genetic trends for both traits over the last 25 years.

## MATERIALS AND METHODS

The American Angus Association (AAA) supplied the data and pedigree files used for the analyses. Expected progeny differences (EPD) for mature size have being available since 1992 by the AAA according to the spring sire report of that year (Wilson and Northcutt, 1992). Two random samples of the database consisting of mature cow weights and heights were obtained from the complete data file based on the last digit of the herd code. The first sample contained 23,658 mature weight (MWT) and 13,012 mature height (MHT) records (Table1). The second sample contained 23,698 MWT and 13,310 MHT records. Genetic trends were estimated by plotting the mean EBV by year of birth for animals born between 1979 and 2006. All weights were corrected for body condition score. Cows of different ages were measured and age was fit in the model.

The four-generation pedigree files were included in the analyses and consisted of 43,105 and 44,141 animals for samples 1 and 2, respectively (Table1). The records used were from cows born between 1983 and 2006. The range in ages when cows were weighed was 2 to 11 years with the majority (80%) of records coming from cows between 2 and 6 years of age. Cows had on average 1.7 records for MWT. In contrast to previous studies of mature size in Angus cattle, the current study presented a larger mature cow database and several cows had repeated records, therefore a repeatability was appropriate.

### *Animal Model*

In matrix notation, the mixed linear model used is:

$$y = Xb + Zu + Qc + Ww + e,$$

where y is the vector of observed records, b is a vector of fixed effects of age when measured; a is a vector of random additive genetic effects; c is a vector of random contemporary group effects; W is a vector of random permanent environmental effects of the cows; X, Z, and Q and W are incidence matrices relating b, u, c, and w to y; and e is a vector of random residual effects. Univariate and bivariate analyses were used to estimate genetic parameters for MWT and MHT, with Henderson's (1977, 1984) augmented mixed model equations and the inverse of the four generation relationship matrix (Henderson, 1976; Quaas, 1976).

Univariate and bivariate analyses were used to estimate genetic parameters for MWT and MHT. Estimates of genetic parameters were obtained using the MTDFREML programs (Boldman et al., 1995) and the animal model used included age as a covariate, and contemporary group, permanent environment of the cow, additive genetic value of the cow and residual as random factors. Contemporary groups were formed using herd and year according to measurement.

## RESULTS AND DISCUSSION

Estimates of variance and covariance components, heritability and repeatability for mature weight and height for samples 1 and 2 are reported in Tables 2 and 3. Results between the two samples were similar. Previous estimates of heritability in the literature show mature weight and height to range from moderate to high. Estimates of heritability

in the current study for MWT ranged from 0.44 to 0.48 and were similar to those reported in previous studies for univariate and bivariate analysis. DeNise and Brinks (1985) reported heritability of 0.44 for MWT, Johnson et al. (1990) presented heritability of 0.38 accounting for lifetime growth curves and Northcutt and Wilson (1993) presented heritabilities for MWT ranging from 0.45 to 0.51 using different models. Heritabilities ranging from 0.69 to 0.72 for cow heights of cows between 2 and 6 years of age were reported by Arango et al., 2002, and Nephawe et al. (2004) reported a similar value of 0.71.

Heritabilities ranging from 0.62 to 0.64 found in the present study were lower than 0.83 reported previously using AAA field data (Northcutt and Wilson, 1993). Conversely, MacNeil et al. (1984) reported a lower estimate of heritability for 7 years-old cows of 0.54. In general, results for MWT and MHT from the current study are mostly in agreement with previous work using field data from the AAA, and the estimates obtained from the current study have smaller standard errors due to number of observations used in the analyses. For MHT some estimates found in the current study are considerably lower than estimates previously reported from AAA field data as discussed above. Contemporary groups accounted for approximately 50% of phenotypic variance for both MWT and MHT. Estimates of repeatability were 0.64 and 0.65 for MWT and 0.77 and 0.70 for MHT for samples 1 and 2, respectively. Brinks et al. (1962), reported repeatability of 0.76 for mature cow weight in Hereford cattle.

Results for correlations between MWT and MHT are presented in Table 4.

Genetic correlations between weight and height were strong and positive ranging from 0.80 to 0.83. These are in agreement with previous studies where estimates ranged from 0.78 to 0.80 (Northcutt and Wilson, 1993; Arango et al., 2002). The permanent environmental correlations were also high, ranging from 0.69 to 0.75. Results from the current study were higher than results found in the literature. Arango et al. (2002) reported permanent environmental correlations for MWT and MHT of 0.55.

The genetic trends derived from Estimated Breeding Values (EBV) from the whole data file for mature weight and mature height are represented graphically in Figures 1 and 2. The MWT trend suggests that MWT has been increasing and recently has begun to plateau. During the ascending time (first 11 years), the regression value for EBV/year was 2.52 kg/year and after the apparent plateau, was 0.29 kg/year. For MHT, there was a positive trend throughout the first 13 years of the data and then a decline for the rest of the years represented in the analysis. The regression value for the positive trend during the first 13 years was 0.2 cm/year and during the negative time was -0.1 cm/year.

Results from the current study, as expected, show that both MWT and MHT would respond favorably to selection due to moderate-high estimates of heritabilities. Also estimated correlations confirmed that changing one trait would lead to a correlated response in the other. Selection would be more accurate for MHT than for MWT because the heritability estimated for MHT is greater and because less variation is due to permanent environmental effects. The repeatability model used provided more accurate results due to the fact that permanent environmental effects were considered in the model.

Ignoring permanent environmental effects in the case of repeated records can lead to overestimates of genetic parameters. These results also show that selection for the total animal effect (genetic plus permanent environmental values) would be considerably more accurate than selection for breeding value allure especially for MWT for prediction of future phenotypes.

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**Table 1.** Summary of data for analyses of mature cow weight (MWT) and mature cow height (MHT) for two samples of Angus cows.

| | Sample 1 | | Sample 2 | |
|---|---|---|---|---|
| | MWT1 | MHT1 | MWT2 | MHT2 |
| No. Records | 23,658 | 13,012 | 23,698 | 13,310 |
| No. Cows | 14,056 | 8,131 | 15,038 | 8,439 |
| No. Cont. Groups | 1,180 | 581 | 1,227 | 692 |
| No. Pedigree | 43,105 | 43,105 | 44,141 | 44,141 |
| Means | 596.6 | 135.7 | 588.3 | 134.3 |

**Table 2.** Estimates of genetic parameters (SD) for mature cow weight (MWT, kg) and mature cow height (MHT, cm) for two samples of Angus cows (single trait analyses).

| | Sample 1 | | Sample 2 | |
|---|---|---|---|---|
| Estimates | MWT1 | MHT1 | MWT2 | MHT2 |
| Heritability[1] | 0.45 (0.012) | 0.64 (0.018) | 0.48 (0.011) | 0.62 (0.018) |
| Repeatibility[1] | 0.64 | 0.77 | 0.66 | 0.70 |
| Cont. Group[2] | 0.50 | 0.52 | 0.52 | 0.46 |
| Phenotypic Variance | 5012.78 | 36.27 | 5332.92 | 33.02 |

[1] fraction of phenotypic variance not including contemporary group variance.

[2] fraction of phenotypic variance including contemporary group variance.

**Table 3.** Estimates of genetic parameters for mature cow weight (MWT, kg) and mature cow height (MHT, cm) for two samples of Angus cows (two trait analyses).

| | Sample 1 | | Sample 2 | |
|---|---|---|---|---|
| Estimates | MWT1 | MHT1 | MWT2 | MHT2 |
| Heritability[1] | 0.44 | 0.62 | 0.47 | 0.62 |
| Repeatability[1] | 0.64 | 0.76 | 0.66 | 0.70 |
| Cont. Group[2] | 0.50 | 0.53 | 0.52 | 0.46 |
| Phenotypic Variance | 5009.21 | 36.08 | 5285.49 | 32.65 |

[1] fraction of phenotypic variance not including contemporary group variance.

[2] fraction of phenotypic variance including contemporary group variance.

**Table 4**. Estimates of correlations between mature cow weight (MWT) and mature cow height (MHT).

| | Sample 1 | | | Sample 2 | | |
|---|---|---|---|---|---|---|
| | Genetic | PE | Residual | Genetic | PE | Residual |
| **Correlations** | 0.80 | 0.75 | 0.15 | 0.83 | 0.69 | 0.18 |

PE: Permanent Environmental effect.

**Figure 1.** Genetic trend for cow weight (MWT).

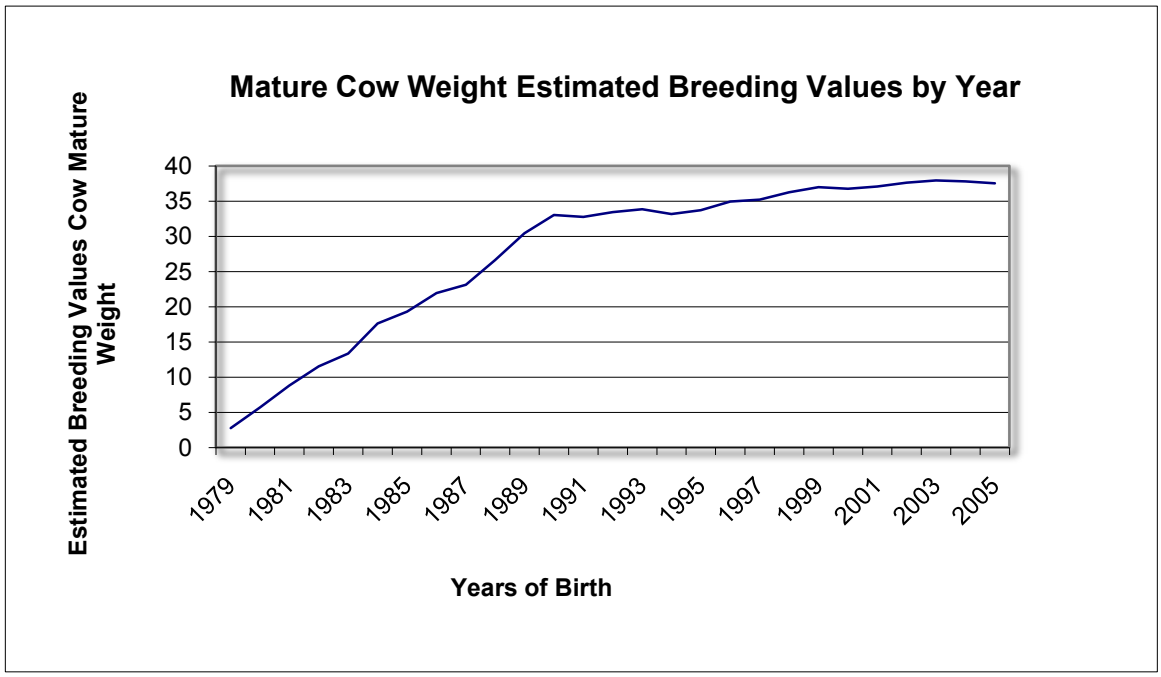

**Figure 2.** Genetic trend for cow height (MHT).