EFFECTS OF RUMINALLY DEGRADABLE NITROGEN IN DIETS CONTAINING WET DISTILLER'S GRAINS WITH SOLUBLES AND STEAM-FLAKED CORN ON FEEDLOT CATTLE PERFORMANCE AND CARCASS CHARACTERISTICS

A Dissertation

by

CHRISTIAN HERNAN PONCE

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

August 2010

Major Subject: Animal Science

EFFECTS OF RUMINALLY DEGRADABLE NITROGEN IN DIETS CONTAINING WET DISTILLER'S GRAINS WITH SOLUBLES AND STEAM-FLAKED CORN ON FEEDLOT CATTLE PERFORMANCE AND CARCASS CHARACTERISTICS

A Dissertation

by

CHRISTIAN HERNAN PONCE

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Approved by:

Co-Chairs of Committee,	Jason Sawyer
	Michael Brown
Committee Members,	Stephen Amosson
	Tryon Wickersham
	Thomas Welsh
Head of Department,	Gary Acuff

August 2010

Major Subject: Animal Science

ABSTRACT

Effects of Ruminally Degradable Nitrogen in Diets Containing Wet Distiller's Grains
with Solubles and Steam-flaked Corn on Feedlot Cattle Performance and
Carcass Characteristics. (August 2010)

Christian Ponce, B. En.., Army Polytechnic School at Quito, Ecuador;
M.S., West Texas A&M University
Co-Chairs of Advisory Committee: Dr. Jason Sawyer
Dr. Michael Brown

Wet distiller's grains with solubles are the most common feedstuff generated by the ethanol industry, and this feedstuff has been utilized by the feedlot industry. Exploration of the effect of dietary distiller's inclusion on the form and quantity of protein or nitrogen (N) has received little attention. Assessment of degradable N needs in diets containing wet distiller's grains with solubles (WDGS) is needed to aid the cattle feeding industry in managing feed costs and potential environmental issues. In Exp. 1, 525 yearling steers (initial weight = 373 ±13 kg) received treatments in a 2 × 3 + 1 factorial. Factors included corn WDGS (15 or 30% of DM) and non-protein N (NPN; 0, 1.5, or 3.0% of DM) from urea. The control diet without corn WDGS contained 3.0% NPN (1.06% urea) and cottonseed meal. Overall gain efficiency among steers fed 15% corn WDGS was greatest for 1.5% NPN and least for 0% NPN ($P = 0.07$, quadratic), whereas gain efficiency decreased linearly ($P < 0.09$) as NPN increased in the 30% WDGS. Dressing percent was greater ($P < 0.01$) for the control diet than for 15% or 30%

WDGS. In Exp. 2, 296 steer calves (initial BW = 344 ± 12 kg) were adapted to a common finishing diet, blocked by BW, and assigned to treatments. Experimental diets included a control diet without WDGS (contained 3% NPN from urea, and cottonseed meal) and 15% WDGS with either 1.50, 2.25, or 3.00% NPN (0.52, 0.78, and 1.04% urea, respectively, on a DM basis). Overall gain efficiency on either a live or adjusted basis was not different among treatments ($P > 0.15$). Dietary NPN concentration did not influence growth performance ($P > 0.21$). Results suggest that optimum performance for cattle fed 15% WDGS occurred when the diet contained between 1.5% and 2.25% NPN. However, removing all supplemental NPN was necessary to support optimum performance in diets containing 30% WCDG.

ACKNOWLEDGEMENTS

I would like to thank Dr. Brown and my committee members Drs. Sawyer, Amosson, Wickersham, and Welsh, for their guidance and support during my life in graduate school and throughout the course of this research.

Thanks also go to my friends and colleagues and the department faculty and staff of West Texas A&M and Texas A&M University for such a great experience.

I would also like to extend my gratitude to my family, especially to my mother and father for their encouragement. Finally, I also appreciate the love and support of my girlfriend.

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

CHAPTER I

INTRODUCTION

Beef cattle production is an important segment of agriculture worldwide. Current feed prices and the volatility of those prices have influenced cattle feeding profitability. The Livestock Marketing Information Center (2008) reported that returns during the past 10 years for the cattle feeding industry have ranged from positive returns of $50/animal to negative returns of $150/animal, with negative returns being the most frequent. This characteristic has influenced utilization of alternative by-products as producers strive to replace more costly dietary ingredients. The boom in ethanol production has been facilitated by current political decisions to adopt new fuel sources (e.g., the renewable fuel standard of the Energy Policy Act of 2005). This dramatic increase in ethanol production has lead to a concomitant increase in the production of distiller's grains. Wet distiller's grains with solubles (WDGS) is the most common feedstuff generated by the ethanol industry, and this feedstuff has been utilized by the feedlot industry. Previous research has focused almost exclusively on elucidating optimum inclusion rates of distiller's grains in finishing rations with various forms of processed grain. However, economic circumstances in the future might favor utilization of WDGS at higher rates than those declared optimum for beef cattle in certain locations of the US. Further, exploration of the effect of dietary WDGS inclusion on the form and

---

This dissertation follows the style of Journal of Animal Science.

quantity of protein or N needed awaits study. Therefore, the objective of the proposed experiments was to determine the effects of dietary crude protein and ruminally degradable protein concentrations on utilization of WDGS in diets based on steam-flaked corn.

CHAPTER II

LITERATURE REVIEW

Ethanol Production

The production and use of alternative fuel sources has been adopted by the US government in order to decrease environmental pollutant emissions as stipulated in the Clean Air Act. Specifically, there are three factors that have contributed to accelerated growth of the ethanol industry: 1) passage of the Clean Air Act amendments by Congress in 1990, 2) replacement of the fuel oxygenate methyl tert-butyl ether (MTBE) with ethanol, and 3) the opportunity to spur rural development (Bothast and Schlicher, 2005).

Ethanol is produced by both the dry and wet grain milling process (Tjardes and Wright, 2002). However, dry grinding is the most common process (67% of total ethanol production). The process involves five general steps: grinding, cooking, liquefaction, saccharification, and fermentation. Endproducts of this process include ethanol, carbon dioxide, residual grain particles, and yeast cell mass.

According to Bothast and Schlicher (2005), grain is immersed with water to produce a mash, in a relationship of approximately 1 to 22 (i.e., 1 bushel of corn [25.4 kg] generates 75.7 L of mash) after corn has been ground through a hammermill (passing a 0.6-mm screen). In order to obtain ethanol by yeast fermentation, starch has to be broken down to monomer glucose units. Therefore, the mash is adjusted to a pH of 6.0, alpha-amylase is added, and the mash is heated to approximately 100˚C to generate soluble dextrins and destroy any preexisting microogranims. Liquefaction of this treated mash is accomplished by holding the temperature at 85˚C and adding additional alpha-amylase for at least 30 minutes to reduce the size of the soluble dextrins. Following liquefaction, the mash is cooled (temperature not specified) and adjusted to a final pH of 4.5 in order to facilitate the action of glucoamylase. Glucoamylase serves to catalyze the conversion of dextrins into glucose. Once glucose is available, the material is ready for fermentation at 32˚C with yeast. It has been a common practice to add supplemental N in the form of urea to allow optimum growth of yeast. Fermentation requires up to 72 h, but is commonly between 48 and 50 h. After fermentation is complete, the final concentration of ethanol is approximately 12%. Therefore, distillation and dehydration are required to separate ethanol from the liquid fraction of the mash to yield purified ethanol (i.e., 100% alcohol or 200 proof).

Ethanol has been introduced in reformulated gasoline as an alternative, renewable fuel source. Reformulated gasoline, used in vehicles, is a blend of gasoline and oxygenates. Oxygenates produce maximum gasoline burning and optimize gasoline carbon oxidation during combustion. Additionally, oxygenates reduce harmful tailpipe emissions from motor vehicles by replacing components such as benzene and sulfur with oxygenates (Howard et al., 1997). The most common oxygenates are MTBE and ethanol. Historically, MTBE has been chosen over ethanol primarily for its blending characteristics and for its lower cost compared to ethanol. However, the Energy Policy Act of 2005 has considered ethanol as a less harmful additive than MTBE because MTBE has been implicated in water contamination from fuel storage tanks. Currently, ethanol constitutes approximately 90% of total US consumption of oxygenates (EIA, 2007).

Replacement of MTBE by ethanol in reformulated gasoline requires approximately 5.7% ethanol in the mixture, and this mixture has an energy content of 111,836 btu/gallon (2% lower than conventional gasoline with MTBE; Shapouri et al., 2002). Gasoline blenders have included a 10% blend of ethanol to comply with the Energy Policy Act of 2005. Ethanol-based fuel needs to be less expensive than gasoline in order to be competitive with traditional gasoline, due to the lower energy value of 100% ethanol (30% less than gasoline; Shapouri et al., 2002). Therefore, the price spread between these fuels likely influences consumer decisions (Hurt et al., 2006). In addition to the broader economic climate surrounding ethanol production (i.e., oil prices, efficiency of production, federal incentives, etc.), ethanol production has raised controversial debates in the community about the efficiency and environmental consequences of the entire process from crop inputs to ethanol formation as well as potential direct and indirect changes in the use of available land resources brought by shifts in commodity prices. For instance, greater biofuel production from corn might decrease production of crops such as rice and soybeans.

According to the U.S. Environmental Protection Agency’s calculation, corn ethanol reduces the total life cycle emissions (i.e., including international and domestic land use changes, fuel production, fuel and feedstock transport, tailpipe emissions, and net agriculture emissions) by 16% compared to emissions produced by gasoline (Darlington et al., 2009). On Other hand, Searchinger at al. (2008) stated that corn-based ethanol may produce approximately twice the greenhouse gas emissions that conventional gasoline would produce over 30 years. The authors assumed that 12.8 millon hectares of U.S. corn production will be used for ethanol production (i.e., 10.8 million hectares of new cropland required for biofuels). Additionally, the model proposed by Searchinger et al. (2008) suggested that land converted to farming will release 25% of the stored soil carbon. The corn production denoted by these authors might not be relevant to U.S. corn production in the near future. Methodology on green house gas G emissions from land use changes utilizes various assumptions which might exaggerate or underestimate mathematical approaches. It is certainly unclear what the actual negative or positive effects of ethanol production may have on the environment. Further, conclusive models are required to determine the true effect of ethanol incorporation as a fuel source.

Ethanol Co-products

The main co-products formed by the dry milling industry, condensed distiller's solubles and wet distiller's grains, are available for use as animal feed. The wet distiller's grains can be partially or fully dried to produce modified wet distiller's grains (48% DM) or dried distiller's grains (90% DM) respectively. Most commonly, condensed distiller's solubles are blended with wet distiller's grains and are marketed as WDGS. Condensed distiller's solubles can also be used as liquid supplement in animal diets (QDG, 2009).

Ethanol plants in the Texas Panhandle are currently producing 250 million of gallons of ethanol/year (Renewable Fuels Association, 2009) from grains. At current production efficiency, it is expected that approximately 1 million tons of distiller's grains with solubles (primarily wet) will be produced primarily from corn. Additionally, Texas has long been considered the largest cattle feeding region. Approximately 20% of the US fed cattle production has remained in this region for more than a decade (NASS, 2009). Therefore, utilization of ethanol co-products in growing and finishing diets is expected if economics are favorable. Utilization of this feedstuff by feedlot cattle depends on various factors such as product availability, chemical-nutritional characteristics, economic suitability, handling characteristics, etc. The cost of weight gain by feedlot cattle, influenced by the cost/megacalorie of NE_m or NE_g, plays an important role when selecting ingredients for inclusion in finishing diets (Brown et al., 2006). Additionally, the cost implications of handling these co-products and the associated impact on the efficiency of feeding and milling operations are important considerations.

Benefits and Limitations of Dry Milling Co-products

As noted previously, there are generally four ethanol co-products available for inclusion in feedlot diets. However, this review will address the benefits and constraints of WDGS, because this ingredient represents the vast majority of co-products marketed in the Texas High Plains area (QDG, 2009).

Limited and variable information is available related to nutritional characteristics of WDGS. Guiroy et al. (2007) reported an NEg value of corn WDGS between 1.54 to 1.85 Mcal/kg (0.70 to 0.84 Mcal/lb), based on nutritional composition. DeClerck (2009) determined an NE_g value of 1.85 Mcal/kg for corn WDGS when steers received 15% corn WDGS in a diet based on steam-flaked corn. However, NE_g was 1.57 Mcal/kg when 30% corn WDGS was fed. Hicks et al. (2007) described NEg concentrations based on performance of 1.37, 1.16, and 1.42 Mcal/kg for 10, 20 and 30 % corn WDGS inclusion, respectively, in diets based on steam-flaked corn. These values are variable and differ from one author to another, and it is likely that attributes of specific products fed and/or other experimental methods contribute to these apparent inconsistencies.

Beef cattle rations are compromised of a mixture of individual feeds, and the energy value of a ration is driven by the energy contributed by these individual dietary ingredients. In addition, it is commonly assumed that the energy value of individual ingredients will be the same when they are fed in combination with other feeds unless data exist to the contrary. Thus, unknown associative effects might occur when dietary ingredients are fed together (Hart, 1987). To our knowledge, there are no data available that identify additive or associative effects of corn WDGS with other dietary ingredients. However, the greater dietary NDF associated with including corn WDGS might be a reasonable factor to consider. Indeed, NDF (from forage especially) is usually associated with increases in dry matter intake and dilutions of dietary NEg (Galyean and Defoor, 2003). Therefore, caution must be exercised when considering estimates of ingredient NE based on animal performance or chemical composition due to the potential of unknown positive or negative associative effects.

Even though processing methods are partially homogeneous across ethanol plants, certain deviations of methods due to technologies employed at specific plants might explain some of the variation in nutritive value of the co-products. Holt and Pritchard (2004) determined nutrient variations of wet distiller's grains and condensed solubles among four ethanol plants on four consecutive days on four different occasions at each plant. Sampling technique represented producer conditions when receiving corn co-products. Results from their report suggested a considerable variation across plants for DM, protein, ADF, NDF, ash, sulfur and fat of WDGS. Dry matter values for WDGS ranged between 29.52 to 36.48%. Indeed, the blending ratio of wet grains to solubles on a given occasion may cause variation on DM, fat, and sulfur content.

Sniffen et al. (1992) detailed the protein profile of wet corn distiller's grains (not specified if it contained condensed solubles) as being 29.5% CP; with 25% of CP as soluble, 65.5% of soluble CP as non-protein N, 12% of CP as ADFIP, and 54.8% of CP as NDFIP. Additionally, Firkins et al. (1985) measured protein degradation characteristics of wet corn distiller's grains (not specified if it contained solubles). These authors determined that the rate of in-situ N disappearance was 3.9%/h, and 47% of the CP present was ruminal escape protein. Crude protein values of up to 37.6% have been determined on samples collected directly from 4 plants (Holt and Pritchard, 2004).

One nutritional limitation of WDGS inclusion can be fat concentration. According to Holt and Pritchard (2004), fat content of corn WDGS averaged 12.1%. In addition, the range for fat content was from 11.04 to 13.12%. Currently, the maximum total dietary fat concentration recommended by consultants in finishing diets is approximately 8% (Vasconcelos and Galyean, 2007). Therefore, the maximum inclusion rate of corn WDGS (as the sole additional source of fat) to not exceed this maximum level of fat would be 60% of diet DM. Excessive dietary fat contributes to inhibition of microbial fermentation, particularly fiber-digesting organisms (Devendra and Lewis, 1974).

Holt and Pritchard (2004) also highlighted elevated sulfur concentration that can exist in wet distiller's grains without solubles (0.38% of DM was the average from 3 plants). However, higher sulfur levels were reported by the same authors for the solubles fraction, ranging from 0.25 to 1.15% DM. Excess dietary sulfur can reduce absorption of copper and selenium (Kincaid, 1988; Spears, 2003). In addition, sulfur interacts with molybdenum in ruminal fermentation where thiomolybdate complexes can be formed when high dietary sulfur is present (Suttle, 1991). Thiomolybdates have been characterized as the principal reason for reduced copper absorption in ruminants with high dietary sulfur intake. The higher affinity of thiomolybdates for copper rather than to proteins involved in transporting copper are responsible for reduced copper storage in tissues with higher dietary sulfur (Suttle, 1991). This antagonistic effect among minerals requires further exploration when sulfur is delivered in WDGS. Determination of adequate levels of dietary minerals needed in practical settings for feedlot cattle is indispensable in order to avoid physiological problems that could result in economic losses from reduced performance or poorer health and potential environmental consequences. Indeed, performance studies on feedlot cattle have elucidated the deleterious effect of inorganic sulfur supplementation (Zinn et al., 1997). The neurological disorder in ruminants characterized as polioencephalomalacia is the primary clinical problem related to high sulfur intake (Gould, 1998).

Inclusion of WDGS might exert a meaningful impact on feeding logistics. The DM content in conjunction with bulk density of WDGS and any change in DM intake by cattle might alter the number of truck loads required for feeding a specific number of cattle. Silva et al. (2007) noted that 23% more loads of feed (as-fed) would need to be delivered when a steam-flaked corn diet contained 15% of diet DM as sorghum WDGS compared to a steam-flaked corn diet without sorghum WDGS, if trucks were loaded to the same total weight. However, Hicks (2008) determined that inclusion of corn WDGS in steam-flaked corn diets decreased the number of truck loads by 13 and 3% when WDGS was included at 10 and 20% of diet DM, respectively. These potential effects on feed delivery will influence costs for fuel and labor, among others. Therefore, these factors need to be considered when determining the cost implications of using WDGS. Furthermore, Hicks (2008) also noted an increase in mixer maintenance when diets containing corn WDGS were prepared.

Utilization of Wet Dstiller’s Grains by Feedlot Cattle

Daubert et al. (2005) analyzed the effects of sorghum WDGS (0, 8, 16, 24, 32 and 40% of DM) on cattle performance. Sorghum WDGS was included in diets based on steam-flaked corn and fed to heifers for 58 d (4 pens/treatment). The basal diet with steam-flaked corn was supplemented with soybean meal and urea. Dietary treatments of 8, 16, and 24% of DM as sorghum WDGS were supplemented with a combination of soybean meal and urea, whereas remaining diets did not contain urea or soybean meal. A quadratic response was noted for cattle performance; optimum performance based on ADG and F:G occurred at 16% WDGS, but WDGS addition of up to 24% of diet DM did not reduce ADG or F:G compared to the control.

Corrigan et al. (2009) evaluated the effect of corn WDGS (0, 15, 27.5 and 40% of DM) in diets based on either steam-flaked, dry-rolled or high-moisture corn fed to steers over 168 d (4 pens/treatment). The control rations contained 1.36% urea and corn gluten meal; corn gluten meal was gradually reduced every 3 wk during the first 126 d of the experiment from 4.3% DM to zero. In addition, the 15% level included 0.5% of DM of urea across all methods of processing and remaining treatments did not receive any protein supplementation beyond that supplied by WDGS. An interaction between corn processing method and corn WDGS was evident for all variables. Gain efficiency increased linearly as corn WDGS increased when diets contained dry-rolled corn, whereas gain efficiency was highest at 27.5% WDGS when diets contained high-moisture corn. For diets containing steam-flaked corn, WDGS did not alter performance and data suggested that corn WDGS could be included up to 40% without any detrimental effect on feed efficiency. Results opposite to these were reported by Trenkle (2008). Trenkle (2008) reported decreased ADG and DMI by non-implanted steers when 40% corn WDGS replaced dry-rolled corn. The primary differences between the methods of Corrigan et al. (2009) and those of Trenkle (2008) were reflected in composition of the control diet. Corrigan et al. (2009) fed primarily urea as the sole source of degrabale N, whereas a blend of urea and soybean meal was fed by Trenkle (2008). Trenkle (1996) indicated that protein supplementation might benefit performance in high-concentrate diets (i.e. dry rolled corn), rather than energy addition by fat supplementation. Protein needs when WDGS are fed will be discussed later in this review.

Data reported by Leibovich et al. (2009) suggest detrimental effects on ADG and G:F when cattle were fed 15% sorghum WDGS, independent of whether the corn fed was processed by steam flaking or dry rolling. Similarly, MacDonald et al. (2008) did not identify an interaction between corn processing method and inclusion of corn WDGS (0 or 20% of DM). However, animals fed 20% corn WDGS tended to have improved feed efficiency compared to those fed 0% corn WDGS averaged across processing methods. On the other hand, May et al. (2009) detected higher DMI, ADG, final BW, and hot carcass weight when steers were fed 15% corn WDGS in diets based on steam-flaked corn compared to diets without WDGS. However, gain efficiency was not altered by corn WDGS inclusion at 15%.

Silva et al. (2007) evaluated the effect of fat concentration in diets containing sorghum WDGS fed to heifers (106 d on feed; 8 pens/treatment). Treatments included diets based on steam-flaked corn with either 0 or 15% sorghum WDGS. In addition, diets with 0% sorghum WDGS contained either 0 or 3% added yellow grease and the 15% sorghum WDGS diets contained 0, 1.5 or 3% yellow grease. Animals fed 15% sorghum WDGS gained faster (5.8%) as a result of greater DM intake compared to animals fed 0%

sorghum WDGS. However, feed efficiency was not affected by sorghum WDGS. Feed efficiency by animals fed 15% sorghum WDGS improved linearly as the level of added fat increased and fat-supplemented heifers had fatter carcasses than heifers that did not receive supplemental fat when 0% sorghum WDGS was fed. Nevertheless, cattle performance was not different among the 0% sorghum WDGS diets with or without added fat. This might indicate a shift on energy partitioning, leading towards fat accretion when animals are supplemented with fat.

High feed prices and volatility of these feed prices might require inclusion of economically feasible products. Previous reviews have indicated that addition of corn or sorghum WDGS at approximately 15% of diet DM in diets based on steam-flaked corn may support optimum energetic efficiency. Inclusion of this corn co-product might exert effects on other ingredients, particularly if economics favor a higher inclusion rate of corn or sorghum WDGS. To our knowledge, there is no information available describing degradable protein requirements when corn is partially replaced by corn or sorghum WDGS.

Protein Requirements of Feedlot Cattle

Previously, the NRC (1985) described a factorial method to quantify the protein requirement for optimum performance by beef cattle. The factorial method accounted for protein needed for maintenance, obligatory metabolic fecal protein, and protein for growth. Protein to support maintenance was derived from scurf protein and endogenous urinary protein, whereas metabolic fecal protein was related to the indigestible portion of dry matter excreted. Protein destined to support growth was considered as the protein found in tissue growth, divided by the efficiency of protein absorption (50%).

Approximately one decade after the factorial method was published, the metabolizable protein system was introduced (NRC, 1996). This system accounts for microbial and for animal tissue needs. Bacterial crude protein synthesis in this system is set at 13% of TDN intake for level 1 of the model. Additionally, bacterial crude protein synthesis is considered equal to the rumen degraded protein (DIP) required, including non-protein nitrogen utilization. However, there is a differentiation between model 1 and 2 in form of protein to meet the DIP requirement, because model 2 includes presumed requirements for peptides. Protein required for tissue maintenance and growth is also characterized in this system. Metabolizable protein for maintenance is considered to be 3.8 g of metabolizable protein/kg of metabolic body weight. Metabolizable protein for tissue growth is defined as retained protein, which can be calculated from the equation: Protein retained, g/d = shrunk weight gain (kg) * (268-(29.4*(retained energy [Mcal/kg])/shrunk weight gain [kg])). The efficiency of metabolizable protein retention is based on the biological value of the protein and the efficiency of use of an ideal mixture of amino acids. Efficiency of protein retention is dependent on body weight because efficiency decreases as body weight increases. The NRC (1996) adopted 49.2% efficiency for cattle weighing more than 300 kg, whereas efficiency is equivalent to 83.4% - (0.114 * EQEBW, kg) for cattle weighing less than 300 kg.

Two sources of metabolizable protein are considered by the NRC (1996). Metabolizable protein from bacteria and metabolizable protein from feed. Metabolizable protein from feed is considered to be 80% of protein that escapes ruminal fermentation (UIP; i.e., 80% digestibility), whereas metabolizable protein from bacteria is equal to 64% of bacterial protein produced (assumes that bacterial protein is 80% true protein and 80% digestible) with an adjustment according to the effective NDF content of the ration in level 1. It is the purpose of this review to concentrate on the effects of DIP on beef cattle performance, particularly on NPN supplementation.

Non-protein Nitrogen Supplementation in Beef Cattle Diets

The utilization of urea as a protein supplement in finishing feedlot diets has been practiced for approximately 50 years (Chalupa et al., 1964). Feed-grade urea is an organic molecule containing 46% N in the form of amine groups. Urea is easily degraded to ammonia and carbon dioxide by ruminal bacteria possessing the enzyme urease. Urea is infinitely soluble in water and is a benign and safe chemical to handle. Urea is produced from synthetic ammonia and carbon dioxide. Large quantities of carbon dioxide are produced during the manufacture of ammonia, mainly from petroleum-derived raw materials. The basic process was developed in 1922, called the Bosch-Meiser urea process after its discoverers (Chalupa et al., 1964).

The benefit of including urea has been to contribute partially to the minimum of 100 g of ruminally degradable protein used to maximize ruminal organic matter digestion and microbial protein synthesis that feedlot cattle require per kilogram of digestible organic matter (Zinn and Shen, 1998). Previously, Burroughs et al. (1975) characterized the urea fermentation potential of various feeds as: urea fermentation potential, g/kg of feed DM consumed = (1.044 × digestible organic matter consumed, g – amount of DIP, g/kg in feed consumed)/2.8, where 1.044 represents the estimated potential net microbial protein (g) synthesized per 10 g of digestible organic matter. However, digestible organic matter accounts for protein and lipid, which ruminal bacteria are unable to utilize for microbial protein yield (Russell et al., 1992).

Ruminal microorganisms require N, energy, and minerals for optimal growth. Sources of N used by bacteria include ammonia-N, peptide-N and amino acid-N (NRC, 1984). Nitrogen utilization by ruminal bacteria is dependent on the type of carbohydrate present in the rumen (Russell et al., 1992). In animals fed high-concentrate diets, the primary type of carbohydrate provided for ruminal fermentation is non-structural carbohydrate (i.e., starch). Microorganisms that utilize non-structural carbohydrates are believed to utilize peptide-N and ammonia-N (Russell, 1992).

Griswold et al. (1996) evaluated the effects of N source (protein-N, peptide-N, amino acid-N and ammonia-N) on microbial growth and ruminal fermentation in continuous culture, simulating the ruminal environment of a dairy cow fed a basal diet consisting of grass hay, alfalfa hay, and a grain mix. Non-structural carbohydrate fermentation was enhanced with either peptides, amino acids, or ammonia by 9% compared with protein-N. Total volatile fatty acid concentration was decreased by urea inclusion. These results indicated that peptides and/or amino acids may be required for microbial growth and rumen fermentation. Indeed, Russell and Sniffen (1984) found an increase in microbial efficiency by bacteria utilizing non-structural carbohydrate as the peptide:organic matter ratio increased. However, microbial efficiency reached a plateau when peptide-N reached 14% of ruminally digested OM. Additionally, Hoover and Stokes (1991) determined that a combination of ammonia, peptides and amino acids allowed mixed ruminal bacteria to have the highest growth rate. Chen et al. (1987) determined under in-vitro conditions that peptides (casein peptides) were metabolized 2.3 times faster than free amino acids (casamino acids; acid digest of casein) by a mixed culture of ruminal bacteria, suggesting preference of ruminal bacteria for peptides.

These data might be related to responses demonstrated in animal performance trials. Heifers (implanted with Synovex H/FinaplixH) fed 10% soybean meal and 0.76% urea gained 15% faster than heifers fed 1.38% urea as the only source of supplemental protein in a diet based on dry-rolled. Feed efficiency was also superior for heifers receiving soybean meal and urea (Trenkle, 1993). Similar findings were detected for steers implanted with Synovex S and Finaplix S (Trenkle, 1993). Trenkle (1995) also tested urea and soybean meal combinations during winter and summer seasons fed to finishing steers. Regardless of season, animals receiving 10% soybean meal and 0.55% urea performed better than animals fed solely 1.97% urea (8% higher ADG and feed efficiency improved by 5%). Similarly, Healy et al. (1995) reported optimum performance when supplemental NPN compromised up to 2/3 of total supplemental CP in diets based on steam flaked corn.

Cooper et al. (2002) conducted two experiments to determine the optimum DIP needed by feedlot cattle fed high-grain diets. In experiment 1, diets based on high-moisture corn were supplemented with 0, 0.4, 0.8, or 1.2% urea (DM basis) to provide dietary DIP values of 7.0, 8.2, 9.3, and 10.5% of DM, respectively. In experiment 2, diets based on steam-flaked corn contained 0, 0.4, 0.8, 1.2, 1.6, or 2.0% urea (DM basis) to provide dietary DIP levels of 4.7, 5.8, 7.0, 8.2, 9.3, and 10.5% of DM, respectively. Performance by cattle fed high-moisture corn was optimized with high levels of urea (10.1% DIP, predicted value using non-linear regression analysis), but cattle fed steam-flaked corn had optimum feed efficiency when urea was included between 0.8 and 1.2% DM (predicted DIP was 7.1% DM using non-linear analysis).

Duff et al. (2003) evaluated the effect of urea inclusion (0, 0.5, 1.0, 1.5 and 1.75 %) in diets based on steam-flaked sorghum using steers and heifers fed for an average of 137 d. Animals were conservatively implanted (Synovex S or Synovex H once only). Cattle receiving 0 and 0.5% urea also received 4.9 and 1.2% of diet dry matter as soybean meal, respectively, but urea was the sole N source for remaining treatments. Overall cattle performance was not altered by urea inclusion; however, the authors noted a numeric improvement of 4.9% in average daily gain by the 1% urea compared to the 0% urea (or soybean meal alone). Likewise, carcass characteristics were not influenced by urea concentration.

Generally speaking, an appropriate level of urea supplementation falls at approximately 1% of diet DM for diets based on steam-flaked corn. In fact, this value is currently utilized widely by the feedlot cattle industry (Vasconcelos and Galyean, 2007). However, current tendencies exist to include co-products of the wet and dry milling industry to attempt to reduce feed costs and maintain or enhance performance, but no data are available to determine what adjustments in DIP may be needed when WDGS are fed.

Non-protein Nitrogen in Diets with Steam-flaked Corn and Corn-coproducts

The optimum level of DIP in diets in which steam-flaked corn is partially replaced by wet corn gluten feed was studied by Block et al. (2005). Treatments included a control diet based on steam-flaked corn with urea as the only added protein, whereas the remaining treatments involved combinations of wet corn gluten feed and steam-flaked corn across a number of targeted dietary urea concentrations. Specifically, diets containing 20% wet corn gluten feed received 0.62, 0.87, or 1.13% urea. Diets containing 30% wet corn gluten feed received 0.15, 0.40, or 0.65% urea, and diets containing 40% wet corn gluten feed received 0 or 0.19% urea. Steers were fed for 166 d and the implant strategy consisted on Synovex-S on d 1 and Revalor-S on d 70 of the experiment. Results from this experiment suggest that optimum feed efficiency occurred at 20% wet corn gluten feed (3% higher than control diet). Among the 20% wet corn gluten feed diets, a positive linear effect of urea concentration on ADG and gain efficiency was evident. Similarly, steers fed 30% wet corn gluten feed gained faster and were more efficient as urea level increased in the diet. However, an optimum range of urea supplementation seemed to be between 0.40% to 0.65% DM. Additionally, steers fed 40% wet corn gluten feed performed similarly whether they were fed 0 or 0.19%, suggesting that protein from the basal ingredients provided adequate DIP.

Stalker et al. (2007) evaluated the effect of urea inclusion (0, 0.4, 0.8, 1.2 and 1.6% of diet DM) in diets containing 30% dry distiller’s grains with a basal diet of 58% ground corn cobs and 12% sorghum silage with individually-fed yearling heifers.

During the 84-d feeding period, urea supplementation did not alter DMI, ADG or feed efficiency. Based on the NRC (1996) model, MP was in excess of what was presumably required for this diet. Urine samples were taken for 5 d beginning on d 46 to determine allantoin and creatinine concentrations, as indicators of microbial protein production. The allantoin:creatinine ratio tended to decrease as urea level increased in the diet. Therefore, N recycling might have played an important role in overcoming potential ruminal deficiencies in DIP at 0 and 0.4% urea inclusion.

Vasconcelos et al. (2007) fed 200 steers for 137d to determine the effect of urea (0.68, 0.89 and 1.09% of DM) in diets based on steam-flaked corn and containing 10% sorghum WDGS, or a control diet based on steam-flaked corn (8.4% DIP). Cottonseed meal (5.19% DM) and urea (1% DM) were included in the control diet. Addition of urea to diets with 10% sorghum WDGS decreased DMI and ADG in a linear fashion; however, feed efficiency did not differ among treatments. In addition, the control diet supported better performance throughout the entire feeding period compared to diets with sorghum WDGS. It is not clear why feed intake was reduced in this study because previous data (Silva et al., 2007) suggest that including sorghum WDGS would dilute dietary energy density and promote increased feed intake.

Steam-flaked corn is the most common processed form of corn fed in the Texas Panhandle (Vasconcelos and Galyean, 2007). Therefore, substantial and reliable characterization of factors affecting the utilization of corn WDGS by finishing cattle in diets based on steam-flaked corn are required. The DIP requirement when steam-flaked corn is partially replaced by corn or sorghum WDGS is unknown. Animal performance and environmental issues might be improved when appropriate levels of these two factors are achieved.

Hypothesis

We hypothesize that inclusion of corn WDGS in steam-flaked corn diets will decrease the need for ruminally degraded protein. The principal source of energy in steam-flaked corn is starch, and partial replacement of starch by the higher fiber corn WDGS might reduce the ruminal microbial need for N. In addition, economic conditions in the industry at any point in time could favor including more than the optimum inclusion of corn WDGS. Therefore, it is of great importance to determine protein needs to support optimum growth performance by feedlot cattle across a range of dietary corn WDGS inclusions.

Objectives

Evaluate the effects of NPN in diets containing up to 30% corn WDGS on feedlot performance and carcass characteristics of yearling steers fed steam-flaked corn. We speculate that the more commonly used level of corn WDGS in our region will be approximately 15% of DM. Therefore, a second experiment is proposed to capture more closely the effect of NPN on performance when a maximum of 15% corn WDGS is fed.

CHAPTER III

MATERIALS AND METHODS

All procedures and protocols used in these experiments were reviewed and approved by the Amarillo-Area Cooperative Research, Education, and Extension Triangle Animal Care and Use Committee (protocol number 2008-03)

Experiment 1

Animal management and treatments

Five hundred sixty-four crossbred steers were procured from an order buyer. One hundred-nine steers were transported for 2517 km from an auction market in Lakeland, Florida, whereas remaining steers traveled an average of 338 km from Oklahoma and were purchased from the country. Steers were processed within 48 h after arrival and adapted to a high-concentrate diet over at least 21 d. Processing included individual identification, vaccination against viral antigens of IBR, PI_3, and BVD type I and II (Vista 3; Intervet/Schering-Plough Animal Health, Millsboro, DE), administration of a clostridial bacterin-toxoid (Vision 7 with Spur; Intervet/Schering-Plough Animal Health), treatment for internal and external parasites (Ivomec Plus, Merial Ltd., Duluth, GA; and Safe-Guard, Intervet/Schering-Plough Animal Health), excision of existing implant(s), horn tipping and implanting with Revalor-IS (Intervet/Schering-Plough Animal Health).

Two days before the experiment began, steers were weighed before feeding to obtain a sorting weight. Five hundred-fifty steers were selected for the study and blocked by body weight into 8 blocks based on sorting weight. Treatments were randomized to pens and steers were randomly assigned to treatments within block. Steers were weighed again the first day of the experiment before the first feeding of the day and were sorted into treatment pens at that time as they exited the chute. Steers then were moved to their respective study pen and treatments began when feed was delivered later that morning. Initial weight for the study was the average of the body weight determined on these two days. Scales used for weighing procedures were validated with 22.68 kg of certified weights before use and calibrated when needed.

Treatments were arranged in a 2 × 3 + 1 factorial of corn WDGS (15 or 30% of DM) and 0, 1.5, or 3.0% NP N derived from urea; a control diet based on steam-flaked corn was also fed in which protein was supplied by urea (3.0% NPN) and cottonseed meal to result in dietary CP of 13.5% (Table 1). Animals assigned to received 30% corn WDGS first received 15% corn WDGS for at least 3 d with the appropriate non-protein urea level before receiving 30% corn WDGS to prevent potential digestive or feed refusal problems.

Steers were housed in 56 pens containing up to 10 steers each. Pens were soil-surfaced (167 m^2), contained a concrete fenceline bunk of 3 m/pen, and every pen was equipped with a single automatic water tank. Water tanks were cleaned weekly throughout the feeding period. Steers were weighed before the morning feeding and reimplanted on d 51and weighed before feeding before shipping to the abattoir. Steers were on feed an average of 129 d. At each weighing day, feed bunks were cleaned and any feed remaining was collected and weighed to determine DM content. In addition, oarts resulting from spoilage due to any reason were removed, weighed, DM determined, and dry quantity refused deducted from DM offered. Scales used for feed refusals were validated before each use with certified weights and calibrated as needed.

Cattle health was visually evaluated once daily during the experiment. Unhealthy cattle were pulled for further examination, appropriate treatment was administered, and cattle returned to their home pen unless isolation was warranted. Cattle determined to be noncompetitive were removed from study to avoid any possible detrimental effect on that particular pen that was not related to treatment.

Blood samples were collected from all animals via jugular venipuncture before feeding on d 1 and at the end of the feeding period to determine plasma urea nitrogen concentration from pen composites. Blood samples were collected using 10-mL vacutainer tubes containing Lithium heparin (Becton Dickinson, Franklin Lakes, NJ) and centrifuged for 20 min at 3,000 × g. An aliquot of plasma from every steer was obtained and they were composited within pen in a 5-mL storage tube and stored at - 70°C until analyzed. A direct colorimetric assay based on diacetylmonoxime was utilized for plasma urea nitrogen determination (Stanbio Laboratory, Boerne, Texas).

Table 1. Ingredient and analyzed chemical composition of experimental diets (DM basis; Exp. 1)

		Corn WDGS, % of DM					
		15%			30%		
		NPN, % of DM			NPN, % of DM		
Item	Control	0	1.5	3.0	0	1.5	3.0
Steam-flaked corn	76.47	66.50	66.49	66.48	52.57	52.57	52.56
Cottonseed meal	3.87	-	-	-	-	-	-
Urea[a]	1.06	-	0.52	1.06	-	0.52	1.06
Wet corn distiller's grains with solubles	-	14.85	14.85	14.84	29.73	29.73	29.72
Supplement[b,c,d]	2.39	3.43	2.93	2.40	3.44	2.92	2.40
Steep liquor	4.12	4.12	4.12	4.12	4.13	4.13	4.13
Yellow grease	2.01	0.99	0.99	0.99	-	-	-
Alfalfa hay	10.09	10.11	10.10	10.11	10.13	10.12	10.12
DM, %	82.73	69.95	69.98	70.02	60.80	60.83	60.86
CP, %	13.61	12.87	15.03	15.60	16.56	18.11	18.94
DIP[e], %	8.59	6.78	8.28	9.83	8.91	10.40	11.96
Non-protein N, %	3.25	0.60	1.80	3.30	0.60	1.75	3.10
ADF, %	8.00	9.95	9.95	9.45	11.75	12.45	11.25
NDF, %	13.85	15.40	18.45	17.45	20.05	22.55	20.35
Crude fat, %	4.85	5.05	4.85	4.85	4.65	4.85	4.50
Ca, %	0.99	0.88	0.87	0.86	0.93	0.89	0.80
P, %	0.33	0.36	0.37	0.35	0.42	0.43	0.41
K, %	0.78	0.81	0.84	0.82	0.90	0.90	0.87
Mg, %	0.20	0.21	0.21	0.20	0.23	0.24	0.21
S, %	0.17	0.23	0.24	0.24	0.31	0.32	0.30
Na, %	0.19	0.21	0.21	0.21	0.22	0.23	0.22
Zn, mg/kg	81	85	88	79	90	92	85
Fe, mg/kg	214	342	241	262	259	279	230
Mn, mg/kg	54	50	46	45	50	54	45
Cu, mg/kg	21	19	18	21	20	20	19

[a] Urea was included in the supplement, but is presented separately for clarity. Urea was replaced with ground corn in the diet (i.e., lower supplement inclusion rate) for treatments with 0% NPN,

.[b] Supplement for the 0% NPN diets contained (DM basis): 30.286% ground corn; 50.420% limestone; 5.714% potassium chloride; 2.542% magnesium oxide; 7.886% salt; 1% yellow grease; 0.001% cobalt carbonate; 0.112 copper sulfate; 0.002% ethylenediamine dihydroiodine; 0.148% manganese oxide; 0.429% Selenium premix (0.2% Se); 0.415% zinc sulfate; 0.197% vitamin A; 0.077% vitamin E; 0.482% Rumensin (Elanco Animal Health, Indianapolis, IN); and 0.289% Tylan-40 (Elanco Animal Health).

[c] Supplement for the 3% NPN diets contained (DM basis): 30.286% urea; 50.420% limestone; 5.714% potassium chloride; 2.542% magnesium oxide; 7.886% salt; 1% yellow grease; 0.001% cobalt carbonate; 0.112 copper sulfate; 0.002% ethylenediamine dihydroiodine; 0.148% manganese oxide; 0.429% Selenium premix (0.2% Se); 0.415% zinc sulfate; 0.197% vitamin A; 0.077% vitamin E; 0.482% Rumensin (Elanco Animal Health, Indianapolis, IN); and 0.289% Tylan-40 (Elanco Animal Health).

[d] Supplement for the 1.5% NPN diets contained a blend (50:50, DM basis) of supplements for 0% and 3% NPN diets.

[e] DIP values calculated using values from Table 2.

Table 2. Protein and net energy values for dietary ingredients

Ingredient	CP, % DM	DIP, % CP	DIP, % DM	NE$_m$, Mcal/kg	NE$_g$, Mcal/kg
Steam flaked corn[a,b,c]	8.0	43.0	3.4	2.41	1.69
Cottonseed meal[c]	46.1	57.0	26.3	1.79	1.16
Steep liquor[f]	17.4	67.2	11.7	2.08	1.40
Yellow grease[a]	-	-	-	4.74	3.51
Alfalfa hay[b,c]	17.0	82.0	13.9	1.24	0.68
Urea[c]	281.0	100.0	281.0	-	-
Wet corn distillers grains with solubles[e]	33.4	52.0	17.5	-	-

[a] NE values obtained from previous trials conducted at WT research feedlot (Ponce et al., 2006 for steam-flaked corn and Silva et al., 2007 for yellow grease)

[b] CP values from composite sample of ingredients derived from monthly samples collected throughout the study.

[d] NE values obtained from NRC 2000

[c] DIP values obtained from NRC 2000

[e] DIP, calculated from chemical analyzed crude protein fractions from table 3 as described by Sniffen et al. (1992). The K$_P$ value assumed was 3.5%/h, whereas K$_d$ values were: 150%/h, 3.5%/h, and 0.1%/h for B1, B2 and B3 fractions, respectively (NRC, 2000).

[f] CP value obtained from Wagner et al. (1983) and DIP value obtained from Patterson et al. (2001).

Table 3. Analyzed chemical composition of wet distiller's grains with solubles[a] (Exp. 1).

Item	Concentration
DM, %	37.71
CP, %	33.40
Soluble CP, % of CP	13.50
NPN, % of CP	0.10
ADICP, %	5.20
NDICP, %	8.55
ADF, %	18.70
NDF, %	36.25
Lignin, %	6.15
Starch, %	4.80
Crude fat, %	12.25
Ash, %	5.71
Ca, %	0.08
P, %	0.65
K, %	0.72
Mg, %	0.23
Na, %	0.16
Cl, %	0.20
S, %	0.57
Cu, mg/kg	5.00
Fe, mg/kg	111.50
Mn, mg/kg	16.00
Mo, mg/kg	0.90
Zn, mg/kg	55.00
DCAD, mEq/100 g	-15.50

[a] From analysis of a composite sample of WDGS (90:10corn:sorghum) derived from weekly bunk samples collected throughout the study.

Experimental diets and dietary ingredients

Feed bunks were evaluated visually every morning approximately at 0700 by trained personnel to determine the amount of feed to deliver to each pen that day. Feed calls were decided with the goal of maintaining 0 to 0.25 kg of feed remaining in the bunk. If feed bunks were empty for 2 consecutive days, feed calls were increased depending on bunk score history during previous 7 d and days on feed. Diets were manufactured and fed twice/d (beginning at 0800 and 1400) using a stationary paddle mixer (Model No. 84-8; Roto-Mix, Inc., Dodge City, KS). During batch preparation, all dietary ingredients (except for supplements) were not allowed to exceed ± 0.5 to 1 kg (as-fed basis). Supplements were prepared in advance and weighed in a different scale with a sensitivity of ± 23 g and manually delivered into the mixer. Scale resolution on the mixer and on the surge was 0.454 kg. In addition, our dietary delivery tolerance from the feed truck was ± 0.454 kg from the quantity of feed called. Adequate cleanout time, in the mixer and surge between treatment preparations, was allowed to decrease potential carryover effect of the previous treatment prepared. Additionally, any dietary surplus was collected and disposed appropriately to avoid treatment contamination.

Steam-flaked corn was prepared approximately 4 times/wk. Generally, corn was steamed for 35 minutes after tempering to 18% moisture overnight and was flaked to a bulk density of approximately 347 g/L. Samples were collected every 20 minutes during flaking and composited for analysis. Flake moisture average 20.58% and starch availability (Xiong et al., 1990) averaged 55.2% (percentage of total starch) during the study. The corn WDGS were obtained approximately 3 times/wk from the White

Energy ethanol plant in Hereford, TX, and corn WDGS were stored under shelter in an open-front commodity barn until consumed. Grain composition of WDGS consisted of 90% corn and 10% sorghum

Samples of corn WDGS and steam-flaked corn were collected 5 times/wk for DM determination (forced-air oven at 60°C for at least 48 h) and a portion of each corn WDGS sample was air-dried and composited for later analyses (Table 3). The amount of the samples was regulated relative to pan surface area, to allow complete drying of the sample. Dry matter of remaining ingredients was determined once/wk. Ingredient dry matter content was used to calculate ration dry matter content each week and to determine actual dry composition of the ration over the course of the study. Feed samples were taken directly from the feed bunks on a weekly basis, dried in a forced-air oven at 60°C for at least 48 h, and ground in a Wiley mill to pass a 2-mm screen. Diet samples were composited and analyzed in duplicate for crude protein (Method 988.05; AOAC, 1990), non-protein nitrogen, ADF (Method 973.18; AOAC, 1990), NDF (Vogel, et al., 1999), ether extract, and minerals. Corn WDGS samples were analyzed in duplicate (Table 2) for crude protein, protein fractions, ADF, NDF and minerals by a commercial laboratory (Dairy One laboratories, Ithaca, New York).

Carcass evaluation

Cattle were shipped to a commercial slaughter facility when cattle were estimated to have a fat thickness of approximately 1.3 cm based on visual appraisal. Personnel from the West Texas A&M University Beef Carcass Research Center collected complete carcass data on the kill floor and in the cooler and one individual recorded railed-out carcasses that were trimmed. Hot carcass weight used for railed-out carcasses was the greater of actual hot weight recorded or hot weight calculated based on the pen average dressing percentage.

Statistical analysis

Parametric data were analyzed as a randomized complete block design using the Mixed procedures of SAS. Pen was the experimental unit and the model included NPN concentration, WDGS concentration, and NPN × WDGS as fixed effects to test for the interaction, whereas the model included the fixed effect of treatment (n=7) in the absence of an interaction. Block served as a random effect in all models. The same model was used to analyze nonparametric data using GLIMMIX procedures of SAS. Interactions were declared meaningful at a $P < 0.15$, and means were declared different at $P < 0.10$. Contrasts to separate means included linear and quadratic effects of non-protein N (within WDGS level if an interaction was detected), control vs 15% WDGS, control vs 30% WDGS, and 15 vs 30% WDGS.

Experiment 2

Two hundred ninety-six calves previously used in receiving trials with a wash-out period of at least 30 d were used. Animals were weighed to obtain a sorting weight and were implanted with Revalor-XS (Intervet/Schering-Plough Animal Health). Within five days, animals were weighed a second time before the first feeding of the day and sorted into treatment pens as they exited the chute. Cattle were moved to their respective study pen and treatments began later that morning when feed was delivered. Initial weight for the study was the average of these two body weight measures.

Treatments included 1.50, 2.25, or 3.00% NPN derived from urea in diets containing 15% corn WDGS and a control diet based on steam-flaked corn and supplemented with 3.0% NPN and cottonseed meal to 13.5% dietary CP (Table 4). Similar to experiment 1, corn WDGS samples were collected through the experiment for chemical analysis (Table 5). Grain composition in this experiment averaged 78% corn and 22% sorghum. Animal management, feeding, and feed manufacturing followed the same procedures as detailed previously for Exp. 1.

Parametric data were analyzed as a randomized complete block design using the Mixed procedures of SAS. Pen was the experimental unit and the model included treatment as fixed effect and block as a random effect. Nonparametric data were analyzed with the same model using GLIMMIX procedures of SAS. Means were declared different at $P < 0.10$. Contrasts included linear and quadratic effects of non-protein N and control vs. the average of 15% WDGS.

Table 4. Ingredient and analyzed chemical composition of experimental diets (DM basis; Exp. 2)

		15% Wet distiller's grains		
		NPN, % of DM		
Item	Control	1.50	2.25	3.00
Steam-flaked corn	76.16	66.21	65.71	65.45
Cottonseed meal	3.61	-	-	-
Wet corn distiller's grains with solubles	-	15.41	15.41	15.41
Supplement[a,b,c]	3.20	2.70	2.96	3.21
Steep liquor	3.99	3.98	3.99	3.98
Yellow grease	4.07	2.77	3.00	3.02
Alfalfa hay	8.95	8.92	8.93	8.93
DM, %	80.35	67.76	67.82	67.83
CP, %	13.05	13.65	14.50	15.25
DIP[d], %	8.16	8.02	8.74	9.45
Non-protein N, %	2.85	1.65	2.25	2.80
ADF, %	8.60	9.20	9.90	9.65
NDF, %	15.10	17.35	18.15	18.40
Crude fat, %	6.75	6.15	6.35	6.45
Ca, %	0.70	0.80	0.735	0.74
P, %	0.28	0.32	0.33	0.32
K, %	0.70	0.75	0.82	0.78
Mg, %	0.19	0.18	0.25	0.20
S, %	0.17	0.23	0.25	0.24
Na, %	0.17	0.19	0.20	0.20
Zn, mg/kg	70.00	69.00	74.50	72.00
Fe, mg/kg	133.00	131.00	162.50	329.00
Mn, mg/kg	47.00	43.50	44.00	65.00
Cu, mg/kg	17.00	13.00	17.00	17.00

[a] Supplement for the 1.5% NPN diets contained (DM basis): 19.85% urea; 55.078% limestone; 7.491% potassium chloride; 3.332% magnesium oxide; 10.427% salt; 1% yellow grease; 0.002% cobalt carbonate; 0.147 copper sulfate; 0.002% ethylenediamine dihydroiodine; 0.193% manganese oxide; 0.562% Selenium premix (0.2% Se); 0.544% zinc sulfate; 0.258% vitamin A; 0.101% vitamin E; 0.632% Rumensin (Elanco Animal Health, Indianapolis, IN); and 0.379% Tylan-40 (Elanco Animal Health).

[b] Supplement for the 2.25% NPN diets contained (DM basis): 27.133% urea; 50.191% limestone; 6.826% potassium chloride; 3.036% magnesium oxide; 9.242% salt; 1% yellow grease; 0.001% cobalt carbonate; 0.134 copper sulfate; 0.002% ethylenediamine dihydroiodine; 0.176% manganese oxide; 0.520% Selenium premix (0.2% Se); 0.496% zinc sulfate; 0.235% vitamin A; 0.092% vitamin E; 0.576% Rumensin (Elanco Animal Health, Indianapolis, IN); and 0.346% Tylan-40 (Elanco Animal Health).

[c] Supplement for the control and the 3% NPN diets contained (DM basis): 33.125% urea; 45.956% limestone; 6.25% potassium chloride; 2.78% magnesium oxide; 8.534% salt; 1% yellow grease; 0.001% cobalt carbonate; 0.123 copper sulfate; 0.002% ethylenediamine dihydroiodine; 0.161% manganese oxide; 0.469% Selenium premix (0.2% Se); 0.454% zinc sulfate; 0.216% vitamin A; 0.084% vitamin E; 0.527% Rumensin (Elanco Animal Health, Indianapolis, IN); and 0.316% Tylan-40 (Elanco Animal Health).

[d] DIP values calculated using values from Table 2 except for WDGS (CP = 32.37 % DM and DIP = 52.26% CP).

CHAPTER IV

RESULTS AND DISCUSSION

Dietary Composition and Physical Characteristics of Wet Corn Distiller's Grains

Analyzed chemical composition of diets generally agreed well with formulation targets (Table 1 for Exp 1 and Table 4 for Exp 2). These data were derived from a composite of weekly samples collected from the bunk. Rations were balanced for equalized fat and forage content, and CP was allowed to increase with increasing NPN. The corn WDGS from Experiment1 was derived from a blend of milo and corn (10:90; Table 3) during the course of the study. However, corn WDGS was derived from a greater blend of milo and corn (22:78; Table 5) for Experiment 2.

Dietary samples were collected during Exp. 1 from the bunk to determine ration density (Figure 1.1). Uncompacted density was determined by pouring a fresh ration sample into a 11.4-L bucket and removing excess feed with a straight edge. Compacted ration density was determined in a similar fashion except that feed was compacted by lifting the filled bucket 30 cm and dropping it 10 times, and then excess feed was removed with a straight edge. These ration densities were determined on 6 separate occasions during the study.

Uncompacted ration densities were different (412, 458 and 479 ± 7 g/L for 0, 15 and 30% corn WDGS, respectively) between 0 and 15% corn WDGS and 15 vs 30% corn WDGS ($P < 0.001$). Compacted densities were also different (525, 592 and 632 ± 6 g/L for 0, 15 and 30% corn WDGS, respectively) between 0 vs 15% WDGS and 15 vs 30% WDGS ($P < 0.001$). Results from these data suggest that ration density increased as corn WDGS level increased in the diet.

Although ration density increased with WDGS concentration, diets containing WDGS were wetter (82.7%, 69.98, and 60.83% for 0, 15, and 30% WDGS, respectively) and cattle consumed a similar amount of DM (Table 6) when fed the control (9.75 kg/d) or diets with WDGS (9.62 kg/d). These data were collected to assess potential implications of WDGS on feeding logistics.

Table 5. Analyzed chemical composition of wet distiller's grains with solubles[a] (Exp. 2)

Item	**90:10[b]**	**80:20[b]**	**70:30[b]**
DM, %			
CP, %	33.00	32.45	32.37
Soluble CP, % of CP	14.50	12.50	10.00
ADICP, %	4.35	4.80	4.65
NDICP, %	9.40	9.95	11.25
ADF, %	16.00	16.60	16.95
NDF, %	32.60	34.85	33.30
Lignin, %	3.10	5.20	4.65
Starch, %	3.55	6.00	5.25
Crude fat, %	13.45	14.65	14.50
Ash, %	5.14	5.14	5.13
Ca, %	0.07	0.08	0.04
P, %	0.87	0.83	0.80
K, %	0.96	0.92	0.91
Mg, %	0.34	0.32	0.31
Na, %	0.15	0.17	0.18
Cl, %	0.19	0.22	0.20
S, %	0.69	0.70	0.74
Cu, mg/kg	7.50	7.00	7.00
Fe, mg/kg	138.50	122.00	126.00
Mn, mg/kg	25.50	20.00	16.50
Zn, mg/kg	57.00	55.00	56.00

[a] From WDGS composite samples collected weekly throughout the study.

[b] Ratio of corn:milo inclusion rates of WDGS. 90:10, 80:20 and 70:30 were fed during 13, 95, 83 d, respectively.

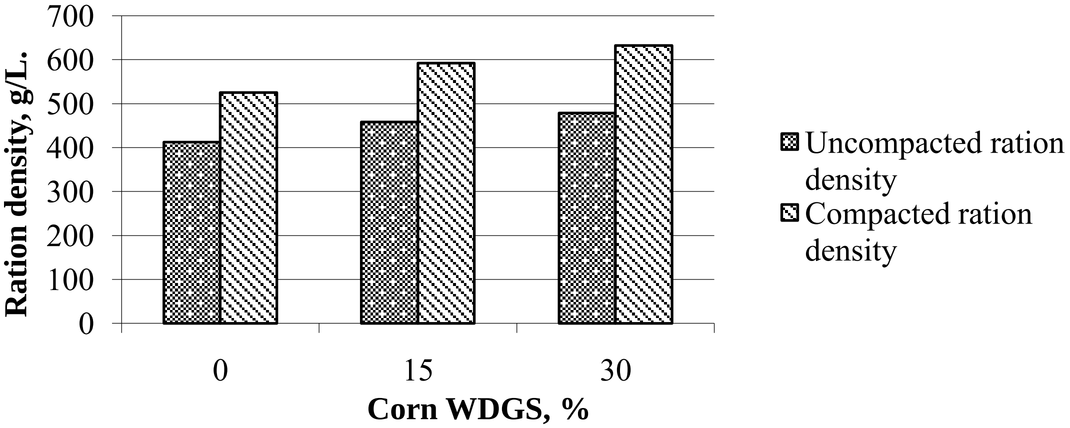

Figure 1. Density of experimental diets. Uncompacted and compacted ration densities were different between 0 and 15 % corn WDGS and 15 vs 30% WDGS ($P < 0.001$)

Assuming that trucks would be filled to the same total weight with or without WDGS, the quantity of feed to deliver would be increased by 14% for 15% WDGS and by 30% for 30% WDGS compared to the control using compacted density. Assuming that trucks would be filled to the same total volume, feeding 15% WDGS would require 3% more feed to deliver than if feeding 0% WDGS and feeding 30% WDGS would require 11% more loads of feed than if feeding 0% WDGS.

Additionally, temperature was measured on samples collected for density determination. Diets containing 15% WDGS were 1.4 ˚C warmer than control diets (30.6 vs 29.2 ˚C, respectively; $P < 0.001$), whereas diets containing 30% WDGS were 1.3 ˚C warmer than 15% WDGS (31.9 vs 30.6 ˚C, respectively; $P < 0.001$). It is unclear whether temperature of feed consumed might impact DM consumption, but we speculate that during summer (i.e. where Exp. 1 occurred), negative effects on DMI might occur. Decreased DMI has been observed during hot weather conditions. This physiological characteristic helps to bring metabolic heat production in balance with the capacity of the animal to dissipate heat (Gaughan and Mader, 2009). To our knowledge, this variable has not been addressed before and awaits further exploration.

Our present data also suggest that more feed (as-fed basis) must be manufactured and delivered when WDGS partially replace steam-flaked corn, and corroborate previous findings in our facilities (Silva et al., 2007). Previously, Silva et al. (2007) determined that animals fed 15% sorghum WDGS required 10% more loads of feed per day compared to animals receiving 0% sorghum WDGS on an equal volume basis or 23% more loads of feed per day on an equal weight basis. Effects of WDGS on feeding logistics were also monitored by Hicks (2008). Results from that study determined that inclusion of corn WDGS in steam-flaked corn diets decreased the number of truck loads by 13 and 3% when WDGS was included at 10 and 20% of diet DM, respectively. However, utilization of 30% WDGS increased the number of loads by 7%. Variation in DM content of WDGS might exert a significant effect on ration density and could explain differences between studies. The DM content of WDGS utilized by Hicks (2008) trial was 2% lower than our corn WDGS. Further data are required to define more specifically the effects on dietary ingredients on feeding logistics.

Throughout the experiment 1 (April through August 2008), an inventory of WDGS was maintained by using scale tickets at the point of purchase (Hereford, TX), the quantity actually fed as described by batch records, and any quantity discarded. The inventory loss that was unaccounted for was declared as shrink, and shrink averaged 6.2% during that time. Although these data are not replicated, they serve to gain insight on real costs that can be incurred when using wet ingredients.

Table 6. Effects of wet distiller's grains with solubles and non-protein N on performance by finishing steers (Exp. 1)

		WDGS, % of DM						
		15%			30%			
		NPN, % of DM			NPN, % of DM			
Item	Control	0	1.5	3.0	0	1.5	3.0	SE
N	8	8	8	8	8	8	8	-
Initial body weight, kg[a]	373	374	372	372	372	373	373	13
Final body weight, kg[a,h,i]	600	597	611	598	588	587	588	12
Adjusted final body weight, kg[b,h,i]	600	591	600	598	586	585	586	9
d 1 to 55								
DMI, kg/d[d,h]	9.36	8.93	9.11	9.38	8.79	8.89	9.23	0.28
ADG, kg/d[h,i]	2.04	1.91	2.02	2.08	1.91	1.91	1.91	0.07
DMI:ADG[c,f,h,i]	4.59	4.69	4.54	4.51	4.63	4.67	4.87	0.14
d 1 to end								
DMI, kg/d[d]	9.75	9.47	9.78	9.82	9.45	9.45	9.76	0.26
ADG, kg/d[c,e,f,i]	1.71	1.67	1.78	1.74	1.68	1.66	1.67	0.04
Adjusted ADG, kg/d[h,i]	1.76	1.68	1.75	1.74	1.66	1.65	1.65	0.04
DMI:ADG[c,f,g,i]	5.70	5.67	5.50	5.62	5.63	5.70	5.85	0.09
Adjusted DMI:ADG[h,i]	5.54	5.66	5.57	5.64	5.71	5.76	5.94	0.12
Calculated NE values[j,k]								
NE$_m$, Mcal/kg of DM	2.17	2.15	2.17	2.13	2.15	2.14	2.10	-
NE$_g$, Mcal/kg of DM	1.49	1.48	1.49	1.46	1.48	1.47	1.43	-
WDGS[l] NE$_m$, Mcal/kg of DM	-	2.42	2.55	2.29	2.35	2.35	2.19	-
WDGS[l] NE$_g$, Mcal/kg of DM	-	1.55	1.68	1.42	1.65	1.65	1.48	-

[a] A pencil shrink of 4% was applied.

[b] Adjusted BW was calculated as hot carcass weight divided by the overall average observed dressing percent (64.22%).

[c] WDGS × NPN Interaction ($P < 0.15$)

[d] Linear effect of NPN ($P < 0.05$)

[e] Linear effect of NPN within 15% WDGS ($P = 0.07$)

[f] Linear effect of NPN within 30% WDGS ($P < 0.05$)

[g] Quadratic effect of NPN within 15% WDGS ($P = 0.02$)

[h] Control vs 30 % WDGS ($P < 0.09$)

[I] 15 vs 30% WDGS ($P < 0.02$)

[j] Dietary NE values calculated from performance data using energy requirements equations for maintenance and shrunk weight gain from NRC (1996).

[k] Determined using the standard reference weights of 435, 462, and 478 for < 26.8, 26.8 to 27.7%, and > 27.7% empty body fat (NRC, 1996); empty body fat was determined by the equation from Guiroy et al. (2001).

[l] Actual NE$_m$ and NE$_g$ were determined by the replacement technique using the NE values shown in Table 2 (NRC, 1996).

Table 7. Effects of non-protein nitrogen on performance by finishing steers fed 15% wet distiller's grains with solubles (Exp. 2).

		15% WDGS						
		NPN, %DM				Contrasts[c]		
Item	Control	1.5	2.25	3.0	SE	1	2	3
n	9	9	9	9	-	-	-	-
Initial body weight, kg[a]	344	345	344	344	12	0.51	0.23	0.56
Final body weight, kg[a]	576	596	592	593	9.2	0.002	0.70	0.68
Adjusted final body weight, kg [b]	576	595	590	596	10.5	<0.01	0.92	0.39
d 1 to 71								
DMI, kg/d	7.41	7.93	7.87	7.78	0.20	<0.001	0.20	0.88
ADG, kg/d	1.66	1.79	1.79	1.75	0.04	<0.01	0.28	0.40
DMI:ADG	4.50	4.44	4.39	4.45	0.12	0.40	0.88	0.38
d 1 to slaughter								
DMI, kg/d	7.86	8.46	8.29	8.26	0.15	0.001	0.22	0.65
ADG, kg/d	1.40	1.52	1.50	1.50	0.03	0.003	0.65	0.81
Adjusted ADG, kg/d[b]	1.39	1.52	1.49	1.52	0.04	0.005	0.99	0.49
DMI:ADG	5.65	5.57	5.52	5.50	0.10	0.14	0.40	0.88
Adjusted DMI:ADG[b]	5.69	5.59	5.58	5.46	0.12	0.15	0.25	0.58
Calculated NE values[d,e]								
NE_m, Mcal/kg DM	2.23	2.20	2.23	2.23	-	-	-	-
NE_g, Mcal/kg DM	1.55	1.52	1.54	1.55	-	-	-	-
WDGS[f] NE_m, Mcal/kg DM	-	2.06	2.02	2.05	-	-	-	-
WDGS[f] NE_g, Mcal/kg DM	-	1.39	1.35	1.44	-	-	-	-

[a] A pencil shrink of 4% was applied.

[b] Adjusted BW was calculated as hot carcass weight divided by the overall average observed dressing percent (65.2%).

[c] Contrasts included: 1) control vs average of 15% WDGS, 2) the linear effect of NPN among 15% WDGS, and 3) the quadratic effect of NPN among 15% WDGS.

[d] Dietary NE values calculated from performance data using energy requirements equations for maintenance and shrunk weight gain from NRC (1996). [e] Determined using the standard reference weights of 435, 462, and 478 for < 26.8, 26.8 to 27.7%, and > 27.7% empty body fat (NRC, 1996); empty body fat was calculated using the equation determined by the equation from Guiroy et al. (2001)

[f] Actual NE_m and NE_g were determined by the replacement technique using the NE values showed in table 2 (NRC, 1996).

Final Body Weight

Experiment 1

Final BW (live and carcass-adjusted; Table 6) was less for animals fed 30% ($P \leq 0.09$) than animals fed either 0 or 15% WDGS regardless of NPN supplementation (NPN ×WDGS; $P > 0.15$).

Experiment 2

Final shrunk BW (Table 7) and adjusted final weight were lighter ($P < 0.01$) for the control than for 15% WDGS, but final weight was not affected by NPN on either a live or carcass-adjusted basis.

Dry Matter Intake

Dry matter intake (DMI) in experiment 1 (Table 6) increased linearly as dietary NPN increased in diets containing either 15 or 30% WDGS, both through reimplant ($P = 0.04$) and overall ($P = 0.05$). Similar to this response, Zinn et al. (2003) detected a linear increase in DMI when steers were supplemented with either 0, 0.4, 0.8, and 1.2% urea in diets based on steam-flaked barley (84-d trial), which was supported by a linear increase in the extent of ruminal and total tract starch digestibility as urea concentration increased. This might suggest that the rate of digestion in gastrointestinal tract might be regulating feed intake. Indeed, Zinn and Owens (1983) controlled DMI (1.2, 1.5, 1.8, and 2.1% of body weight) of canulated steers and detected a linear increase on the extent of ruminal starch digestion as DMI increased. Dry matter intake from d 1 to 55 in Exp. 1 was similar between the control and 15% WDGS; however, DMI was lower ($P = 0.06$) for animals fed 30% WDGS than animals fed the control diet. However, overall DMI was not influenced by WDGS. In Exp. 2, greater DMI (d 1 to 71 and overall) was detected ($P < 0.01$) for 15% WDGS than for the control, but DMI was not altered by NPN.

Previously, May et al. (2009) reported decreased DMI when steam-flaked corn was replaced by 25% corn dry distiller's grains. Similar to our results, Leibovich et al. (2009) did not detect differences in DMI by cattle fed 15% sorghum WDGS compared to 0% sorghum WDGS in diets based on steam-flaked corn. More recently, Uwituze et al. (2010) fed either 25% dry distiller's grains or a standard steam-flaked corn diet to feedlot heifers and treatments did not alter DMI.

Average Daily Gain

Experiment 1

Average daily gain (ADG) through reimplant (Table 6) was greater ($P = 0.02$) for the control than 30% WDGS. Similarly, animals fed 15% WDGS gained weight more rapidly than those fed 30% WDGS ($P = 0.02$). Non-protein nitrogen did not influence ADG through reimplant. An interaction between NPN and WDGS was detected in overall ADG ($P = 0.12$). A positive linear effect of NPN was detected ($P = 0.07$) when 15% WDGS was fed, whereas a negative linear effect of NPN was evident ($P = 0.05$) when 30% WDGS was fed. Overall carcass-adjusted ADG was not different ($P > 0.10$) between steers fed the control and those fed 15% WDGS, but steers fed 15% WDGS had greater adjusted ADG than those fed 30% WDGS ($P < 0.05$).

Experiment 2

Average daily gain from d 1 to 71 (Table 7) was increased for animals fed 15% WDGS compared to animals receiving 0% WDGS ($P < 0.01$). Overall ADG (live and adjusted) was higher ($P < 0.01$) for animals fed 15% WDGS than for those fed the control diet. In general, ADG was not altered by supplementation of NPN.

Healy et al. (1995) reported increased ADG when urea was replacing soybean meal, maintaining a constant protein level of 13% (steam flaked corn based diet). Milton et al. (1997) studied the effect of urea supplementation (i.e. either 0, 0.35, 0.70, 1.05 and 1.4% urea levels [DM basis]) on finishing steers fed a dry-rolled corn basal diet. Daily gain, in this particular study, increased quadratically, being the optimum in the range between 0.35 and 0.7% urea. Vasconcelos et al. (2007) detected a linear decrease in live ADG by animals fed 10% sorghum WDGS supplemented with 0.68, 0.89 and 1.09 % of urea, compared to control animals fed 0% sorghum WDGS and supplemented with cottonseed meal and urea. Based on performance and digestibility trials, corn grain has a higher energy value than sorghum grain (Zinn, 1991). This might be reflected in cattle performance when feeding sorghum distiller's compared to corn distiller's.

Feed Efficiency

Experiment 1

Feed efficiency through reimplant (Table 6) was not different ($P > 0.10$) between the control and diets containing 15% WDGS, but feed efficiency was negatively impacted when steers were fed 30% WDGS compared to 15% WDGS ($P = 0.02$). Feed efficiency through reimplant became poorer ($P = 0.03$) as dietary NPN increased for steers fed 30% WDGS, but feed efficiency through reimplant was not altered by NPN for steers fed 15% WDGS (WDGS × NPN, $P = 0.02$). Overall feed efficiency (live-basis) depended on WDGS and NPN (interaction, $P = 0.06$). Feed efficiency was positively improved in a quadratic fashion by NPN in diets containing 15% WDGS (; $P = 0.02$), whereas increasing NPN in diets containing 30% WDGS resulted in a linear increase (poorer) in feed efficiency ($P = 0.07$). Overall, live-based feed efficiency did not differ ($P > 0.10$) between steers fed the control and those fed 15% WDGS. However, feed efficiency was poorer ($P < 0.05$) when 30% WDGS was fed compared to 15% WDGS. Feed efficiency on an adjusted basis was similar between the control and 15% WDGS. However, adjusted feed efficiency was poorer for 30% WDGS compared to 15% WDGS ($P = 0.02$).

Experiment 2

Feed efficiency on either a live or adjusted basis was not altered by WDGS or NPN, but there was a tendency for feed efficiency to be improved ($P < 0.15$) for animals fed 15% WDGS compared to those fed the control. Animals fed WDGS had heavier final weights, supported by eating more and gaining weight more rapidly. However, similar feed efficiency across treatments might reflect a dilution of energy density in the diet when steam-flaked corn and cottonseed meal are partially replaced by WDGS.

Previous research has indicated that supplementation of NPN is not necessary for individually-fed animals receiving a 58% corn cobs based diet with 30% dried distillers grains (Stalker et al., 2007). In addition, Richeson et al. (2006) reported that overall growth performance did not differ when animals received cottonseed meal N:urea N ratios of 67:33, 33:67 or 0:100 in diets containing 25% wet corn gluten feed (CP level fed was 13.5% DM). However, a negative control was not utilized in this particular experiment, and does not allow discerning if N source would have been important at a lower dietary CP. Zinn et al. (1997) showed a negative effect on animal performance as level of CP increased (8, 16, 24, or 32% CP from cottonseed meal) in steam-flaked corn diets. Corresponding dietary CP values were 11.93, 14.82, 17.7 and 20.59 % DM. Average daily gain decreased in a linear manner as CP increased in the diet. Similarly, feed efficiency became poorer as CP increased in the diet. Excess of dietary CP might be the factor related to poorer performance when 30% WDGS was fed in the present experiment.

Zinn et al. (1997) concluded that nitrogen excretion through urine required 7.9 Kcal/gram of N. Previously, Tyrell et al. (1970) determined that 1 gram of excess N required 10.8 Kcal of digestible energy. These findings might suggest a diversion of energy use from growth to maintenance. The liver is the primary site for removal of excess N, and 4.9% of whole-body ATP use might be required for liver protein synthesis through urea cycle enzymatic activity (Chen et al., 1999). Arginase activity in pigs has been increased by 32% when pigs were fed diets with 25% CP compared to diets with 15% CP. Therefore, the steers in the present study may have experienced increased arginine demand with consumption of higher-protein diets. Previously, Zinn and Owens (1993) concluded that arginine might be a limiting amino acid for growth and performance of lightweight steers fed higher concentrations of escape crude protein sources.

Performance by cattle in the present Exp. 1 suggests that replacement of steam-flaked corn with up to 15% WDGS requires including between 1.5 and 3% of diet DM as NPN. Ruminal fermentation and digestibility of 15% WDGS diets might likely require supplementation of at least half DIP of what seem to be the optimum for steam-flaked corn diets.

Data from Exp. 2 might suggest an energy dilution in diets containing WDGS. Dilution might be reflected by sorghum inclusion in ethanol production. This might be particularly supported by the characteristics of the WDGS utilized in Exp. 2 (22% sorghum:78% corn). However, these results agree with findings by May et al. (2009). These authors found increased DMI, ADG and final body weight for steers fed 15% WDGS (10% sorghum:90% corn) compared to animals fed 0% corn WDGS. Previous data suggest that sorghum WDGS contain approximately 24% less NE than the steam-flaked corn and cottonseed meal that were replaced (DeClerk, 2009; Silva et al., 2007). Our present data suggest that 22:78 sorghum:corn WDGS may also have a lower energy content than the ingredients it replaced (Table 7) These present data suggest that between 1.50 and 2.25% NPN supplementation may be needed in diets containing 15% of diet dry matter as 22:78 sorghum:corn WDGS.

These responses need to be contrasted with further research to verify these results, and to clarify possible digestion effects of NPN on WDGS. Furthermore, previous research has demonstrated the benefits of using non-protein nitrogen (urea) for feedlot cattle fed high-concentrate diets. Urea is readily hydrolyzed to ammonia in the rumen, exerting a possible buffering effect by moderating ruminal and systemic acidic upsets (Galyean, 1996).

Contrary to our findings, other experiments have not detected differences in DMI or ADG by steers fed WDGS compared to steers fed 0% WDGS (Firkins et al., 1985; Lodge et al., 1997; Al-Suwaiegh et al., 2002; Vasconcelos and Galyean, 2007; Leibovich et al., 2009). Clearly, differences across studies might reflect variation in wet distiller's grains composition as discussed by Holt and Pritchard (2004). Unfortunately, the authors of the previously mentioned studies in which DMI and ADG did not differ with and without WDGS did not characterize chemical composition of WDGS or the blending ratio of condensed soluble to wet distiller's grains in the WDGS. Therefore, it is difficult to establish an appropriate comparison to our findings. Variation in the amount of solubles added to distiller's grains certainly alters endproduct composition, as they are rich in fat and CP (Holt and Pritchard, 2004). Dry matter values determined by Holt and Pritchard (2004) for solubles were 23% (SD = ± 2.8%). Therefore, addition of a one unit of solubles to distillers grains will impact moisture, CP and fat content of WDGS.

Net Energy Calculations

Calculations of dietary NE_m and NE_g concentrations were made as described by Zinn and Shen (1998) with modifications employed using the empty body fat equation of Guiroy et al. (2001). Observed diet NE_m and NE_g concentration based on cattle performance in both experiments (Table 6) were 98% of tabular values used for the control diet (Table 2); therefore, 2% was discounted from every dietary ingredient to account for that difference. Through the process of substitution, WDGS for Exp. 1 had an NE_g value of 1.55 Mcal/kg when included at 15% across all NPN levels. The highest NE_g was 1.68 Mcal/kg for the diet containing 1.5% NPN and 15% WDGS. In addition, the NE_g value was 1.59 Mcal/kg across all NPN levels for 30% WDGS; NEg was numerically highest (1.65 Mcal/kg) at 0% NPN when 30% WDGS was fed. Data suggest that the NE_g value for WDGS fed in Exp. 1 was 99% of the value for steam-flaked corn that was assumed in the substitution. In Exp. 2, WDGS had NEg values of 1.39, 1.35 and 1.44 Mcal/kg for 1.50, 2.25 and 3.00 % NPN diets, respectively. The mean of these energy values represents 82% of the value we utilized for steam-flaked corn (1.69 Mcal/ kg).

Caution is warranted in interpreting these data because these calculations assume no interactions among dietary ingredients. However, these data provide a useful barometer for nutritionists of the relative energy content of WDGS.

Plasma Urea Nitrogen Concentrations

As, expected no effect of NPN or corn WDGS were evident at d 1 before treatments were applied (Figure 2). No interactions were observed between WDGS and NPN for plasma urea N concentrations at the end of the feeding period in Exp. 1 ($P >$ 0.74). As the level of corn WDGS increased, plasma urea N increased as well (control vs 15% [$P < 0.05$], 15 vs 30% [$P < 0.05$]). A linear increase in plasma urea N was evident as NPN increased ($P < 0.01$) in Exp. 1 (Figure 3).

Plasma urea N concentration has been suggested to be an indicator of protein status in ruminants (Johnson and Preston, 1995). As expected, dietary CP drastically influenced on plasma urea N status. The higher plasma urea N might support optimum nitrogen availability for bacterial protein synthesis in diets containing WDGS. However, the very high plasma urea N for the 30% WDGS might indicate supra-optimal nitrogen availability, linked to decreased daily gain and poorer feed efficiency observed. Regardless of treatments imposed in the present study, plasma urea N was higher than what seems to be a suitable value (i. e, 8 mg/dL) to sustain optimum performance and low wastage of nitrogen utilization by animals (Cole et al., 2003). Further research is warranted to elucidate the effect of excess ruminal nitrogen on performance by cattle fed WDGS.

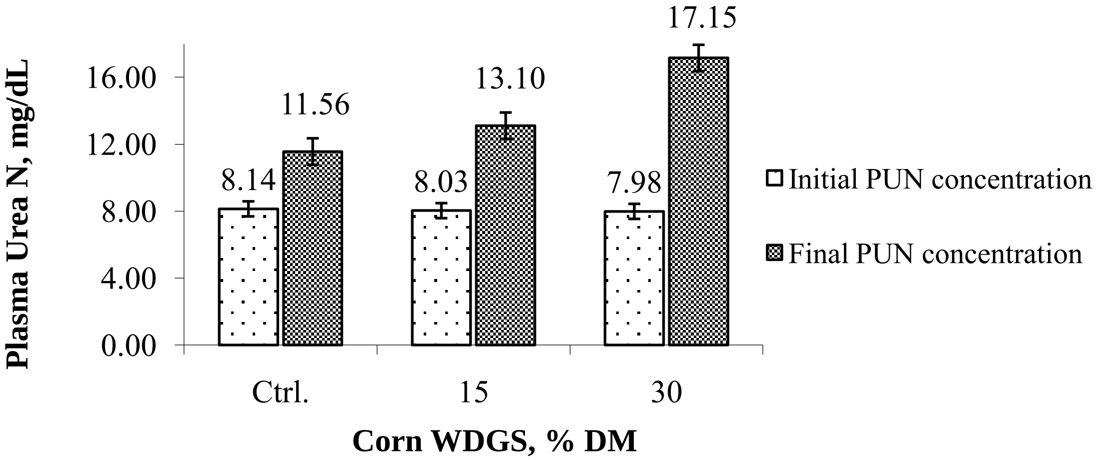

Figure 2. Effects of corn WDGS on plasma urea-N concentration (Exp. 1). Initial plasma urea N (SE= 0.45) did not differ (*P* >0.15). No interaction between WDGS and NPN (*P* >0.15). Final plasma urea N concentration (SE=0.79) was different (*P* < 0.05) for control vs 15% WDGS, control vs 30% WDGS, and 15% vs 30% WDGS.

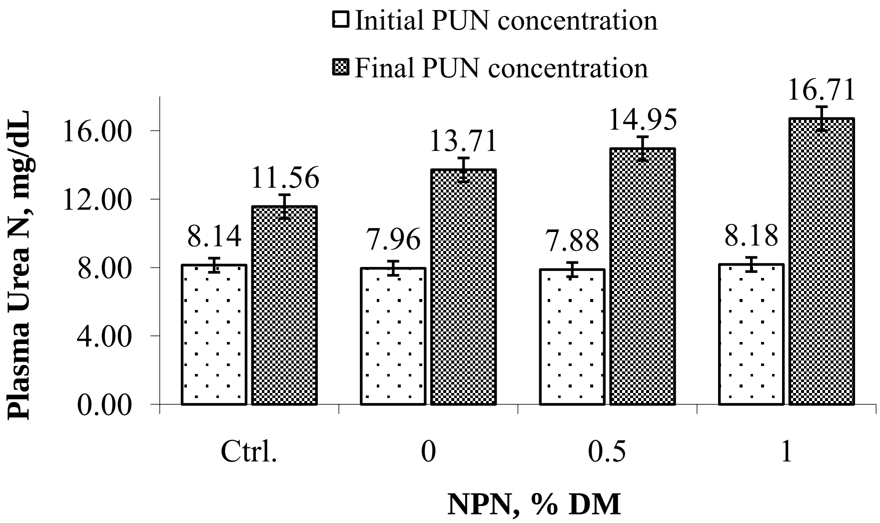

Figure 3. Effects of non-protein N on plasma urea-N concentrations. Initial plasma urea N (SE= 0.45) did not differ (*P* >0.15). No interaction between WDGS and NPN (*P* >0.15). Final plasma urea N concentration (SE=0.70) increased linearly (*P* < 0.01) as NPN increased.

Carcass Traits

Experiment 1

No interactions ($P > 0.15$) between WDGS and NPN were detected for any carcass traits (Table 8). Hot carcass weight was decreased by feeding 30% WDGS compared to feeding 15% WDGS ($P < 0.01$). Similarly, animals fed 30% WDGS had lighter hot carcass weights than the control (P < 0.01). Dressing percent was greater for steers fed the control diet than for those fed either 15 or 30% WDGS ($P < 0.001$). Fat thickness, LMA, yield grade, and marbling score did not differ ($P > 0.10$) between treatments. However, more carcasses from steers fed 30% WDGS were yield grade 1 ($P = 0.04$) than from steers fed other treatments. Steers fed the control had more yield grade 3 carcasses ($P = 0.07$) than those fed 15 or 30% WDGS.

Experiment 2

Hot carcass weight (Table 9) was lower for the control than for 15% WDGS ($P = 0.01$). The control had fewer premium carcasses compared to 15% WDGS ($P < 0.08$). However, other carcass measurements were not different among treatments. In general, results are in agreement to our previous findings in Exp. 1 with the exception that we did not observe a decrease in dressing percent when WDGS was fed. The reasons for this difference are not clear, but we speculate that the greater dry matter intake observed in Exp. 1 for animals fed WDGS might have altered gut fill. Therefore, the effects of feeding WDGS on dressing percent require further explanation.

Table 8. Effects of wet distiller's grains with solubles and non-protein N on carcass characteristics by finishing steers (Exp. 1)

		WDGS, % of DM						
		15%			30%			
		NPN, % of DM			NPN, % of DM			
Item	Control	0	1.5	3.0	0	1.5	3.0	SE
Hot carcass weight, kg[a,b]	385	379	385	384	376	376	376	6
Dressing percent[a,c]	65.12	64.26	63.97	64.28	63.95	64.04	63.94	0.35
Fat thickness, cm	1.24	1.21	1.24	1.29	1.23	1.20	1.25	0.08
LM area, cm^2	92.31	91.10	89.99	91.96	93.21	91.66	92.69	1.53
Yield grade	2.77	2.75	2.86	2.83	2.63	2.67	3.06	0.20
Marbling score[d]	400	387	405	402	395	400	393	11
Premium, %	11.49	4.20	9.20	11.81	9.03	14.65	10.56	-
Choice, %	33.89	36.39	42.05	36.79	35.14	30.21	28.89	-
≥Choice, %	45.38	40.59	51.25	48.59	44.17	44.86	39.44	-
Select, %	54.62	58.02	48.75	48.23	53.75	51.08	57.60	-
Standard, %	0	1.39	0	3.18	2.08	4.06	2.95	-
Yield grade 1, %[b]	14.24	13.85	10.14	11.35	25.14	15.24	22.81	-
Yield grade 2, %	39.90	52.19	47.36	47.26	42.92	49.51	40.17	-
Yield grade 3, %[a,e]	41.53	21.18	35.63	32.50	23.61	32.74	26.88	-
Yield grade 4 and 5, %[e]	4.34	12.78	6.88	8.89	8.33	2.50	10.14	-

[a] Control vs 30% WDGS ($P <$ 0.05).

[b] 15 vs 30% WDGS ($P <$ 0.01).

[c] Control vs 15% WDGS ($P < 0.001$).

[d] Marbling score: 300 = slight; 400 = small, etc.

[e] Quadratic effect of NPN ($P < 0.10$).

Table 9. Effects of non-protein N on carcass characteristics by finishing steers fed 15% wet distiller's grains with solubles (Exp. 2).

		15% WDGS						
		NPN, %DM				Contrasts[a]		
Item	Control	1.5	2.25	3.0	SE	1	2	3
n	9	9	9	9	-	-	-	-
Hot carcass weight, kg	376	388	385	389	6.80	0.008	0.89	0.38
Dressing percent	65.2	65.2	65.0	65.5	0.20	0.88	0.26	0.18
Fat thickness, cm	1.13	1.23	1.18	1.26	0.08	0.29	0.83	0.50
LM area, cm^2	89.18	90.02	88.86	90.94	2.02	0.65	0.61	0.30
Yield grade	2.70	2.88	2.85	2.87	0.13	0.26	0.96	0.91
Marbling score[b]	401	398	412	395	10.40	0.92	0.86	0.18
Premium, %	4.56	8.02	16.75	8.02	-	0.08	1.00	0.02
Choice, %	39.29	30.09	28.11	32.28	-	0.20	0.80	0.68
≥Choice, %	43.85	38.12	44.86	40.30	-	0.69	0.79	0.42
Select, %	53.68	59.11	52.36	55.69	-	0.75	0.64	0.43
Standard, %	2.47	2.78	2.78	4.01	-	0.77	0.70	0.82
Yield grade 1, %	12.24	14.97	12.90	14.81	-	0.68	0.98	0.70
Yield grade 2, %	52.47	40.12	41.80	36.51	-	0.07	0.66	0.62
Yield grade 3, %	32.52	36.57	40.06	36.09	-	0.46	0.96	0.59
Yield grade 4 and 5, %	2.80	8.33	5.24	12.59	-	0.12	0.41	0.25

[a] Contrasts included: 1) control vs average of 15% WDGS, 2) the linear effect of NPN among 15% corn WDGS, and 3) the quadratic effect of NPN among 15% WDGS

[b] Marbling score 300 = slight; 400 = small, etc

Similar to our findings, Leibovich et al. (2009) found a 0.6% decrease in dressing percent for animals fed 15% sorghum WDGS. A 0.7% decrease in dressed yield was also detected by Depenbusch et al. (2008) by feeding animals 25% sorghum WDGS. Contrary to our results, Corrigan et al. (2009) detected a linear increase in dressing percent (63.0, 63.3, 63.9 and 63.8%) as corn WDGS increased (0, 15, 27.5 and 40%, respectively) in diets based on dry-rolled corn. However, these authors did not detect any effect on dressed yield when corn WDGS partially replaced either high-moisture corn or steam-flaked corn, compared to 0% corn WDGS. Results from this experiment are highly speculative because the authors did not measure final body weight. Final body weight in this particular experiment was indirectly calculated from hot carcass weight and adjusted to a common dressing percent of 63%. Dressing percent is an important factor in slaughter cattle pricing systems other than on a live basis; therefore, any decrease dressed yield might alter economic returns for feedlot producer.

The decrease in dressing percent that we observed might be an indicator of alterations of gastrointestinal tract development and/or variation of gut fill. Previously, Rompala et al. (1988) documented a detrimental effect of dietary bulk density on visceral organ mass of sheep. Rompala et al. (1988) fed ewe lambs 1.23 kg of a 72% concentrate control diet daily or 1.25 kg of the control diet enriched with 10% polyethylene powder daily. This feeding regimen provided both groups isoenergetic rations. Weights of gastrointestinal complex weight (i.e., reticulum, rumen, omasum and abomasum), heart, kidneys, lungs and large intestine were greater for lambs fed the polyethylene diet compared to animals in the control group. Results from this experiment warrant close examination because animals were fed as group and variation within treatment of dry matter intake might be an issue. However, the authors reported that variation was limited by training animals to consume the entire meal in 15 minutes after feed was delivered.

Effects on yield grade might be expected from the finishing weights and more rapid weight gain. As feedlot cattle approach finishing weights, body fat deposition increases at a faster rate than other body components (e.g., protein deposition; NRC, 2000). Fatter animals had more yield grade 3 carcasses than treatments in which cattle were less fat. Results from this experiment might suggest that inclusion of 30% corn WDGS might influence fat deposition due to slower ADG observed for cattle fed 30% WDGS. However, we did not detect differences in fat thickness or marbling score across treatments. Previously, Macdonald et al. (2008) noted a decrease in marbling score by animals fed 35% corn WDGS compared to animals fed a standard steam-flaked corn diet. This decrease was explained by a reduction in the monounsaturated:saturated fatty acid ratio of the diet for cattle fed corn WDGS compared to animals fed steam-flaked corn.

Remaining carcass responses observed in this experiment agreed with previous research, where no significant differences were found when animals received WDGS (Larson et al., 1993; Depenbusch et al., 2008). Similar to our data, Shain et al. (1998) did not find any difference in any carcass traits with urea supplementation. Contrary to our results, Milton et al. (1997) detected a linear increase on subcutaneous fat and yield grade as level of urea increased on the diet.

CHAPTER V

CONCLUSIONS

In Exp. 1, animal performance (ADG and feed efficiency) by animals fed 15% WDGS was improved by supplementing between 1.5 and 3% NPN from urea. When 30% WDGS was fed, no benefit was evident in feeding NPN. Furthermore, high plasma urea nitrogen values associated with high dietary CP levels seem to be unfavorable for animal performance. Additionally, chemical values from WDGS samples taken from this experiment may suggest that WDGS haa a DIP value higher than NRC (2000) values. However, rate of digestion of the protein fractions needs to be clearly defined for WDGS to more closely quantify the DIP value of WDGS. The energy value of WDGS based on cattle performance suggests that the NE of WDGS (90:10 corn:sorghum) and steam-flaked corn may be similar. Finally, dressing percent was reduced by feeding WDGS. Therefore, this study suggests further research to elucidate this characteristic. Data from Exp. 2 deviates slightly from findings in Exp. 1, which may be largely explained by the relative grain composition of the WDGS fed. Animals fed 15% WDGS in Exp. 2 gained faster by consuming more feed. The energy value of the co-product might contribute to the dilution of energy observed, as supported by the mathematical calculation.

Differences across experiments beyond the WDGS fed might be attributed to environmental conditions and differences in BW of cattle in both studies. Data from both experiments suggest that between 1.50 and 2.25%% NPN may be needed in diets containing 15% WDGS from a blend of corn and sorghum. Further research is required to elucidate the effects of distillers grains derived from different blends of cereal grains on cattle performance and their interaction with ruminally degraded protein needs. Additionally, possible deleterious effect of WDGS on dressed yield need to be explored.

LITERATURE CITED

Al-Suwaiegh, S., K. C. Fanning, R. J. Grant, C. T. Milton, and T. J. Klopfenstein. 2002. Utilization of distillers grains from the fermentation of sorghum or corn in diets for finishing beef and lactating dairy cattle. J. Anim. Sci. 80:1105-1111.

AOAC. 1990. Official Methods of Analysis (15th Ed.). Association of Official Analytical Chemists, Arlington, VA.

Block, H. C., C. N. Macken, T. J. Klopfenstein, G. E. Erickson, and R. A. Stock. 2005. Optimal wet corn gluten and protein levels in steam-flaked corn-based finishing diets for steer calves. J. Anim. Sci. 83:2798-2805.

Bothast R.J., and M.A. Schlicher. 2005. Biotechnological processes for conversion of corn into ethanol. Appl. Microbiol. Biotechnol. 67:19-25.

Brown, M. S., C. H. Ponce, and R. Pulikanti. 2006. Adaptation of beef cattle to high-concentrate diets: Performance and ruminal metabolism. J. Anim. Sci. 84:E25-E33.

Burroughs, W., D. K. Nelson, and D. R. Mertens. 1975. Evaluation of protein nutrition by metabolizable protein and urea fermentation potential. J. Dairy Sci. 58:611-619.

Chalupa, W., J. L. Evans, and M. C. Stillions. 1964. Metabolic aspects of urea utilization by ruminant animals. J. Nutr. 83:77-82.

Chen, G., H. J. Strobel, J. B. Russell, and C. J. Sniffen. 1987. Effect of hydrophobicity of utilization of peptides by ruminal bacteria in vitro. Appl. Environ. Microbiol. 53: 2021-2025.

Chen, H. Y., A. J. Lewis, P. S. Miller, and J. T. Yen. 1999. The effect of excess protein on growth performance and protein metabolism of finishing barrows and gilts. J. Anim. Sci. 77:3238-3247.

Cole, N. A., L. W. Greene, F. T. McCollum, T. Montgomery, and K. McBride. 2003. Influence of oscillating dietary crude protein concentration on performance, acid-base balance, and nitrogen excretion of steers. J. Anim. Sci. 81:2660-2668.

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

Corrigan, M. E., G. E. Erickson, T. J. Klopfenstein, M. K. Luebbe, K. J. Vander Pol, N. F. Meyer, C. D. Buckner, S. J. Vanness, and K. J. Hanford. 2009. Effect of corn processing method and corn wet distillers grains plus solubles inclusion level in finishing steers. J. Anim. Sci. 87:3351-3362.

Darlington T. L., J. M. Heuss, and D. F. Kahlbaaum. 2009. Review of EPA's RFS2 Lifecycle Emissions Analysis for Corn Ethanol. Available at: http://www.ethanolrfa.org/objects/documents/2624/air_epa_rfs2_comments_september_23.pdf. Accessed Sep. 8, 2009.

Daubert R. W., J. S. Droulliard, E. R. Loe, J. J. Sindt, B. E. Depenbusch, J. T. Fox, M. A. Greenquist, and M. E. Corrigan. 2005. Optimizing use of wet sorghum distillers grains with solubles in flaked-corn finishing diets. Page 15 in Kansas State Beef Cattle Res. Rep. Kansas State Univ. Agric. Exp. Stn. and Coop. Ext. Serv., Manhattan.

DeClerck J.C , 2009. Effects of wet corn and sorghum distillers grain on performance carcass characteristics of finishing beef cattle on *in vitro* fermentation of steam-flaked corn-based substrates. MS Thesis. Texas Tech University, Lubbock.

Devendra C., and D. Lewis. 1974. The interaction between dietary lipids and fiber in sheep. 2. Digestibility studies. Anim. Prod. 19:67–72.

Depenbusch, B. E., J. S. Drouillard, E. R. Loe, J. J. Higgins, M. E. Corrigan, and M. J. Quinn. 2008. Efficacy of monensin and tylosin in finishing diets based on steam-flaked corn with and without corn wet distillers grains with soluble. J. Anim. Sci. 86:2270-2276.

Duff, G. C., K. J. Malcolm-Callis, M. L. Galyean, and D. A. Walker. 2003. Effects of dietary urea concentration on performance and health of receiving cattle and performance and carcass characteristics of finishing cattle. Can. J. Anim. Sci. 83: 569–575.

EIA. 2007. Annual Energy Review. Available at: www.eia.doe.gov/emeu/aer/renew.html. Acccesed Nov. 12, 2008.

Energy Policy Act. 2005. Energy policy Act of 2005. Available at: http://www.epa.gov/oust/fedlaws/publ_109-058.pdf. Accessed Feb. 10, 2010

Firkins, J. L., L. L. Berger, G. C. Fahey, and N. R. Merchen. 1984. Ruminal nitrogen degradability and escape of wet and dry distillers grains and wet and dry corn gluten feeds. J. Dairy Sci. 67:1936-1944.

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

Galyean, M. L., and P. J. Defoor. 2003. Effects of roughage source and level on intake by feedlot cattle. J. Anim Sci. 2003 81:E8-16.

Gaughan, J. B., and T. L. Mader. 2009. Effects of sodium chloride and fat supplementation on finishing steers exposed to hot and cold conditions. J. Anim. Sci. 87:612-621.

Gould, D.H., 1998. Polioencephalomalacia. J. Anim Sci. 76:309-314.

Griswold, K. E., W. H. Hoover, T. K. Miller, and W. V. Thayne. 1996. Effect of form of nitrogen on growth of ruminal microbes in continuous culture. J. Anim. Sci. 74: 483-491.

Guiroy, P. J., D. G. Fox, L. O. Tedeschi, M. J. Baker, and M. D. Cravey. 2001. Predicting individual feed requirements of cattle fed in groups. J. Anim. Sci. 79: 1983-1995.

Guiroy, P. G., J. N. Pike, C. B. Calk, and M. A. Messman. 2007. Corn by-products: Considerations involving variability and formulation. Pages 49-56 in Proceedings of the Plains Nutrition Council Spring Conference. Plains Nutrition Council, Amarillo, TX.

Hart, S. P. 1987. Associative effects of sorghum silage and sorghum grain diets. J.

Anim. Sci. 64:1779-1789.

Healy, B. J., R. T. Brandt, Jr., and T. P. Eck. 1995. Combinations of non-protein nitrogen and natural protein affect performance of finishing steers fed flaked corn diets. J. Anim. Sci. 73(Suppl.1):258 (Abstr.).

Hicks, R.B. 2008. Effect of inclusion of wet distiller's grains in corn based diets on feeding logistics in a commercial feedyard. Pages 64-69 in Oklahoma Panhandle Research and Extension Center, Oklahoma State University, Goodwell.

Hicks, R.B., C.J. Richards, and P.K. Camfield. 2007. Use of distiller's grains (wet & dry) in flaked corn diets for finishing beef cattle. Pages 57-67 in Oklahoma Panhandle Research and Extension Center Research Highlights. Oklahoma State University, Goodwell, Oklahoma.

Holt, S. M., and R. H. Pritchard. 2004. Composition and nutritive value of corn co-products from dry milling ethanol plants. BEEF 2004-01. Pages 1-3 in South Dakota Beef Report. SDAES, Brookings.

Hoover, W.H., and S. R. Stokes. 1991. Balancing carbohydrates and proteins for optimum rumen microbial yield. J. Dairy Sci. 74:3630–3644.

Howard, C. J., A. Russell, R. Atkinson, and J. Calvert. 1997. Ambient air quality effects of oxyfuels. Pages 1.32-1.43 in Interagency Assessment of Oxygenated fuels. National Science and Technology Council, Washington, DC.

Hurt, C., Tyner, W., and Doering, O. 2006. Economics of Ethanol. Available at: http://www.ces.purdue.edu/extmedia/ID/ID-339.pdf. Accessed Feb. 19, 2010.

Johnson, J. W., and R. L. Preston. 1995. Minimizing nitrogen waste by measuring plasma urea-N levels in steers fed different dietary crude protein levels. Pages 62–63 in Texas Tech Univ. Res. Rep.T-5-355. Texas Tech University, Lubbock.

Kincaid, R. 1988. Macro elements for ruminants. Pages 336 – 338, in The Ruminant Animal, Digestive Physiology and Nutrition. D.C. Church, ed. Prentice Hall, Inc. Englewood Cliffs, NJ.

Larson, E. M., R. A. Stock, T. J. Klopfenstein, M, H. Sindt, and R. P. Huffman. 1993. Feeding value of wet distillers byproducts for finishing ruminants. J. Anim Sci. 71: 2228-2236.

Leibovich, J., J. T. Vasconcelos, and M. L. Galyean. 2009. Effects of corn processing method in diets containing sorghum wet distillers grain plus solubles on performance and carcass characteristics of finishing beef cattle and on *in vitro* fermentation of diets. J. Anim Sci. 87:2124-2132.

Livestock Marketing Information Center. 2008. Prices and production. Available at: http://www.lmic.info/ Accessed Nov. 18, 2008.

Lodge, S. L., R. A. Stock, T. J. Klopfenstein, D. H. Shain, and D. W. Herold. 1997. Evaluation of wet distillers composite for finishing ruminants. J. Anim Sci. 75:44-50.

MacDonald, J.C., K. H. Jenkins, E. K. Buttrey, J. B. Lewis, S. B. Smith, R. K. Miller, T. E. Lawrence, F. T. McCollum III, and N. A. Cole. 2008. 35% corn wet distiller's grains plus solubles in steam-flaked and dry-rolled corn based diets: Effects on animal performance. Available at:

http://amarillo.tamu.edu/library/files/jim_macdonald_publications/35_pct_distillers_grains_animal_performance.pdf. Accesed Mar 20, 2010.

May, M., M. J. Quinn, N. DiLorenzo, D. R. Smith, K. E. Hales, D. D. Simms, and M. L. Galyean. 2009. Effects of adding min-ad to steam-flaked corn-based diets with or without wet corn distillers grain plus solubles on performance by beef cattle during receiving and finishing phases. Prof. Anim. Sci. 25:559-568.

Milton, C. T., R. T. Brandt, and E. C. Titgemeyer. 1997. Urea in dry-rolled corn diets: Finishing steer performance, nutrient digestion, and microbial protein production. J. Anim. Sci. 75:1415-1424.

NASS. 2009. Livestock and animal statistics. Available at: http://www.nass.usda.gov/Statistics_by_Subject/index.php. Accessed Dec. 20, 2009.

NRC. 1984. Nutrient Requirements of Beef Cattle, 6th rev. ed. Natl. Acad. Press, Washington, DC.

NRC. 1985. Ruminant Nitrogen Usage. Natl. Acad. Press, Washington, DC.

NRC. 1996. Nutrient Requirements of Beef Cattle. 7th rev. ed. Natl. Acad. Press, Washington, DC.

Patterson, T., T. Klopfenstein, D. J. Jordon, C. Wilson, R. Mass, and R. Stock. 2001. Undegradable intake protein content of corn steep compared to soybean meal. Pages 37-38.in Univ. Neb. Beef Cattle Rep., MP 76-A. University of Nebraska, Lincoln.

Ponce, C. H., M. S. Brown, C. E. Smith, Sr., and L. D. Mitchell. 2006. Effects of grain processing methods on feedlot performance and carcass characteristics of finishing beef steers. Pages 124-1255 in Plains Nutrition Council Proc., Amarillo, TX.

QDG. 2009. Wet distillers grains with solubles. Available at: http://www.qdgllc.net/products.html. Accessed Feb. 17, 2010.

Renewable fuels association. Ethanol Industry statistics. 2009. Available at: http://www.ethanolrfa.org/pages/statistics. Accessed Dec. 20, 2009.

Richeson, J.T., J. D. Rivera, J. J. Cranston, M. D. Abney, and M. L. Galyean. 2006 Effects of proportion of supplemental dietary crude protein supplied by urea on performance and carcass characteristics of beef cattle fed steam-flaked corn-based diets with wet corn gluten feed. Prof. Anim. Sci. 22:33-40.

Rompala, R. E., T. A. Hoagland, and J. A. Meister. 1988. Effect of dietary bulk on organ mass, fasting heat production, and metabolism of the small and large intestines in sheep. J. Nutr. 118:1553-1557.

Russell, J. B. 1983. Fermentation of peptides by Bacteroides rurninicola B14. Appl. Environ. Microbiol. 45:1566-1574.

Russell, J. B., and C. J. Sniffen. 1984. Effect of carbon-4 and carbon-5 volatile fatty acids on growth of mixed rumen bacteria *in vitro*. J. Dairy Sci. 67:987-994.

Russell, J.B., J.D. O’Connor, D.G. Fox, P.J. Van Soest, and C.J. Sniffen. 1992. A net carbohydrate and protein system for evaluating cattle diets: I. Ruminal fermentation. J. Anim. Sci. 70:3551–3561.

Searchinger, T., R. Heimlich, R. A. Houghton, F. Dong, A. Elobeid, J. Fabiosa, S.

Tokgoz, D. Hayes, and T. Yu. 2008. Use of U.S. Croplands for biofuels increases greenhouse gases through emissions from land-use change. Science 319:1238-1240.

Shain, D. H., R. A. Stock, T. J. Klopfenstein, and D. W. Herold. 1998. Effect of degradable intake protein level on finishing cattle performance and ruminal metabolism. J. Anim. Sci. 76:242-248.

Shapouri, H., J.A. Duffield, and M.S. Graboski. 2002. Estimating the Net Energy Balance of Corn Ethanol, Agricultural Economic Report No. AER-721. USDA, Economic Research Service, Office of Energy, Washington, DC.

Silva, J.C., N.A. Cole, M.S. Brown, C.H. Ponce, D.R. Smith. 2007. Effects of dietary fat and wet sorghum distiller's grains plus soluble on feedlot performance and carcass characteristics of finishing heifers. Available at: http://beef.tamu.edu/academics/beef/bcrt/2007.pdf. Accessed August 24, 2008.

Sniffen, C. J., J. D. O'Connor, P. J. Van Soest, D. G. Fox, and J. B. Russell. 1992. A net carbohydrate and protein system for evaluating cattle diets: II. Carbohydrate and protein availability. J. Anim. Sci. 70:3562-3577.

Spears, J. W. 2003. Trace mineral bioavailability in ruminants. J. Nutr. 133:1506S-1509S.

Stalker, L.A., D. C. Adams, and T. J. Klopfenstein. 2007. Urea inclusion in distillers dried grains supplements. Prof. Anim. Sci. 23:390-394.

Suttle, N.F. 1991. The interactions between copper, molybdenum, and sulphur in ruminant nutrition. Annu. Rev. Nutr. 11:121-140.

Tjardes, K., and C. Wright. 2002. Feeding Corn Distiller's Co-Products to beef cattle. Available at: http://agbiopubs.sdstate.edu/articles/ExEx2036.pdf. Accessed Jan. 15, 2010.

Trenkle, A. 1993. Protein requirement of finishing yearling heifers implanted with Synovex H and Finaplix H. A. S. Leaflet R1050, Pages 158-160 in Beef and Sheep Res. Rep. Iowa State Univ., Ames.

Trenkle, A. 1995. Response of finishing steers implanted with estradiol and trenbolone acetate to varying concentrations of dietary urea and soybean meal. A. S. Leaflet R1235. Pages 85-91 in Beef Res.Rep. Iowa State Univ., Ames.

Trenkle, A. 1996. Responses to Adding Fat to Corn-Based Diets Supplemented with Urea and Soybean Meal for Finishing Steers. A. S. Leaflet R1341. Pages 75-80 Beef Res. Rep. Iowa State Univ., Ames.

Trenkle, A. 2008. Value of Wet Distillers Grains in a Cattle Diet without Corn. Leaflet R2287, Available at: http://www.ans.iastate.edu/report/air/2008pdf/R2287.pdf Accessed Mar 20, 2010.

Tyrrell, H. F., P. W. Moe, and W. P. Flatt. 1970. Influence of excess protein intake on energy metabolism of the dairy cow. Pages 69-72 in Proc. 5th Symp. Energy Metab., Vitznau, Switzerland.

Uwituze, S., G. L. Parsons, M. K. Shelor , B. E. Depenbusch, K. K. Karges, M. L. Gibson, C. D. Reinhardt, J. J. Higgins, and J. S. Drouillard. 2010. Evaluation of dried distillers grains and roughage source in steam-flaked corn finishing diets. J. Anim. Sci. 88:258-274.

Vasconcelos, J. T., and M. L. Galyean. 2007. Nutritional recommendations of feedlot consulting nutritionists: The 2007 Texas Tech University Survey. J. Anim. Sci. 85:2772-2781.

Vasconcelos J., L. M. Shaw, K. A. Lemon, N. A. Cole, and M. L. Galyean. 2007. Effects of graded levels of sorghum wet distiller's grains and degraded intake protein supply on performance and carcass characteristics of feedlot cattle fed steam-flaked corn-based diets. Prof. Anim. Sci. 23:467-475.

Vogel, K. P., J. F. Pedersen, S. D. Masterson, and J. J. Toy. 1999. Evaluation of a filter bag system for NDF, ADF, and IVDMD forage analysis. Crop Sci. 39:276–279.

Wagner, J. J., K. S. Lusby and G. W. Horn. 1983. Condensed molasses solubles, corn steep liquor and fermented ammoniated condensed whey as protein sources for beef cattle grazing dormant native range. J. Anim. Sci. 57:542-552.

Zinn, R. A. 1991 Comparative feeding value of steam-flaked corn and sorghum in finishing diets supplemented with or without sodium bicarbonate. J. Anim Sci. 69: 905-916.

Zinn, R. A., E. Alvarez, M. Mendez, M. Montano, E. Ramirez, and Y. Shen. 1997. Influence of dietary sulfur level on growth performance and digestive function in feedlot cattle. J. Anim. Sci. 75:1723-1728.

Zinn, R. A., R. Barrajas, M. Montano, and R. A. Ware. 2003. Influence of dietary urea level on digestive function and growth performance of cattle fed steam-flaked barley-based finishing diets. J. Anim Sci. 81:2383-2389.

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

Zinn, R. A., and Y. Shen. 1998. An evaluation of ruminally degradable intake protein and metabolizable amino acid requirements of feedlot calves. J. Anim Sci. 76: 1280-1289.

VITA

Name: Christian Hernan Ponce

Address:
Department of Animal and Food Sciences
Box 42141
Texas Tech University
Lubbock, TX 79409-2141

Email Address: chpl80@hotmail.com

Education:

B. En. Agriculture Engineer, Army Polytechnic School at Quito, Ecuador. October, 2003

M. S. Animal Science. West Texas A&M University, Canyon, TX, December 2006

Ph.D. Animal Science, Texas A&M University, College Station, TX, August 2010.