South Dakota State University

Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange

Electronic Theses and Dissertations

2024

Evaluation of Soybean Meal Versus Distillers Co-Products as a Protein Supplement for Finishing Beef Cattle: Effects on Growth Performance, Carcass Characteristics, and Efficiency Of Dietary Net Energy Utilization

Cassidy R. Ross
South Dakota State University, cassidyross1@xplornet.ca

Follow this and additional works at: https://openprairie.sdstate.edu/etd2

 Part of the Beef Science Commons

Recommended Citation

Ross, Cassidy R., "Evaluation of Soybean Meal Versus Distillers Co-Products as a Protein Supplement for Finishing Beef Cattle: Effects on Growth Performance, Carcass Characteristics, and Efficiency Of Dietary Net Energy Utilization" (2024). *Electronic Theses and Dissertations*. 968.
https://openprairie.sdstate.edu/etd2/968

This Thesis - Open Access is brought to you for free and open access by Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange. It has been accepted for inclusion in Electronic Theses and Dissertations by an authorized administrator of Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange. For more information, please contact michael.biondo@sdstate.edu.

EVALUATION OF SOYBEAN MEAL VERSUS DISTILLERS CO-PRODUCTS AS A PROTEIN SUPPLEMENT FOR FINISHING BEEF CATTLE: EFFECTS ON GROWTH PERFORMANCE, CARCASS CHARACTERISTICS, AND EFFICIENCY OF DIETARY NET ENERGY UTILIZATION

BY

CASSIDY R. ROSS

A thesis submitted in partial fulfillment of the requirements for the degree

Master of Science

Major in Animal Science

South Dakota State University

2024

THESIS ACCEPTANCE PAGE
Cassidy Rose Ross

This thesis is approved as a creditable and independent investigation by a candidate for the master's degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Warren Rusche
Advisor Date

John Jaeger
Department Head Date

Nicole Lounsbery, PhD
Director, Graduate School Date

ACKNOWLEDGMENTS

First, a very special thank you to Dr. Warren Rusche. Your wealth of knowledge and experience have been an incredible resource. Your willingness to sit with me and help me work through the wide range and numerous questions I have had, while challenging to think deeper has not gone unnoticed. Thank you for the high level of mentorship support you have provided over the last two years. To Dr. Zach Smith, your passion for the field of ruminant nutrition is contagious and has been instrumental in shaping the direction of my education and professional pursuits. It has been a privilege to world alongside you and learn from you. I am confident that the combination of knowledge and personal growth I attained as a member of this lab group would have been attained to near as high of a degree elsewhere.

Paul Schlobohm, your patience is unwavering, and your knowledge and expertise have been a phenomenal resource to me throughout the last two years. As well, thank you Scott Bird for exceptional cattle care at the SERF during my first trial. The lab group is so fortunate to have top quality livestock management at the RNC and SERF.

Thank you to my fellow graduate students who have been with me along the way, Thiago Ribeiro, Forest Francis, Becca Grimes Francis, Santana Hanson, Tommy Norman, Riley Leeson, Grace Olinger, and Justin Delver. You all have made the last two years incredibly special, and I am exceptionally thankful for the memories and friendships formed. I would also like to thank my family and friends back in Canada. Moving away from my support base was challenging but it was made easier knowing you all were just a phone call away.

CONTENTS

ABBREVIATIONS

AA	Amino Acid
ADG	Average Daily Gain
ADF	Acid Detergent Fiber
AFBW	Adjusted Final Body Weight
BW	Body Weight
CDS	Condensed Distillers Solubles
cFBW	Carcass-Adjusted Final Body Weight
CP	Crude Protein
DG	Distillers Grains
DBG	Dried Brewers Grains
DDGS	Dried Distillers Grains Plus Solubles
DM	Dry Matter
DMI	Dry Matter Intake
DP	Dressing Percentage
DRC	Dry Rolled Corn
EE	Ether Extract
EBF	Empty Body Fat
EBG	Empty Body Gain
EBP	Empty Body Protein
EBW	Empty Body Weight
EG	Daily Energy Gain
EM	Maintenance Energy Required

FBW	Final Body Weight
F:G	Feed to Gain
G:F	Gain to Feed
GH	Grass Hay
GIT	Gastrointestinal Tract
HCW	Hot Carcass Weight
HMC	High Moisture Corn
HMEC	High Moisture Ear Corn
KS	Kansas
KPH	Kidney Pelvic Heart Fat
LM	Longissimus muscle
LS	Liquid Supplement
MDGS	Modified Distillers Grains Plus Solubles
MR	Maillard Reaction
MRP	Maillard Reaction Products
N	Nitrogen
NE	Net Energy
NEg	Net Energy for Gain
NEm	Net Energy for Maintenance
NDF	Neutral Detergent Fibre
NRFC	Non-Roughage NDF Content
NH_3	Ammonia
NJ	New Jersey

NPN	Non-Protein Nitrogen
P	*P* - value
pH	Potential of Hydrogen
RCBD	Randomized Complete Block Design
RDP	Rumen Degradable Protein
RE	Retained Energy
REA	Ribeye Area
RF	Rib Fat
RNC	Ruminant Nutrition Center
RP	Retained Protein
RUP	Rumen Undegradable Protein
RY	Retail Yield
SB	Soybean
SBM	Soybean Meal
SBH	Soybean Hull
SERF	Southeast Research Farm
SEM	Standard Error of the Mean
SUN	Sera Urea-N
SWG	Shrunk Weight Gain
TDN	Total Digestible Nutrients
USDA	United States Department of Agriculture
WDGS	Wet Distillers Grains plus Solubles
YG	Yield Grad

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

EVALUATION OF SOYBEAN MEAL VERSUS DISTILLERS CO-PRODUCTS AS A PROTEIN SUPPLEMENT FOR FINISHING BEEF CATTLE: EFFECTS ON GROWTH PERFORMANCE, CARCASS CHARACTERISTICS, AND EFFICENCY OF DIETARY NET ENERGY UTILIZATION

CASSIDY R. ROSS

2024

Two randomized complete block design experiments were conducted to: 1) examine the effects of soybean meal with or without additional soybean hulls in replacement of modified corn distillers grains plus (MDGS) solubles on growth performance efficiency of dietary net energy utilization and carcass traits responses in finishing beef steers, 2) determine if partial or complete replacement of dried distillers grains plus solubles (DDGS) with solvent-extracted soybean meal (SBM) in diets based upon high-moisture ensiled corn influences growth performance, efficiency of dietary net energy utilization, sera urea-N (SUN) concentrations, or carcass traits in finishing beef steers. Experiment 1 was a 118-d finishing experiment conducted at the Southeast Research Farm (SERF) near Beresford, SD using single source, Black Angus influence steers (initial shrunk BW = 435 ± 23.2 kg). This study used 6 replicate pens (24 total pens) of 8 steers assigned to one of three dietary treatments. Dietary treatments included: 1) MDGS fed at 15% diet DM (MDGS), 2) MDGS replaced by soybean meal and corn (9 and 6% of DM, respectively; SBM), 3) MDGS replaced by soybean meal and soyhull pellets (9 and 6% of DM, respectively; SBM-SBH). Steers were blocked by batch fraction and pen served as the experimental unit. The model included the fixed effects of treatment and block. No

differences amongst treatments ($P \geq 0.11$) were observed for carcass-adjusted final BW, dry matter intake (DMI), average daily gain (ADG), or feed efficiency. Dietary treatment had no effect ($P \geq 0.11$) on hot carcass weight (HCW), dressing percentage, ribeye area, rib fat, marbling score, USDA Yield Grade, percent empty body fat (EBF), or final body weight adjusted to 28% empty body fat (EBF). Distribution of USDA Quality or Yield grades were unaffected by treatment ($P \geq 0.39$). Dietary treatment did not affect liver abscess incidence and severity ($P = 0.11$). Net energy values calculated from animal performance agreed closely with tabular estimates with observed to expected ratios for net energy equalling one. In this experiment, feeding supplemental protein sources with enhanced diet conditioning attributes and greater concentrations of ruminally undegradable protein provided no advantage to cattle performance. Experiment 2 was a 139-d finishing experiment conducted at the Ruminant Nutrition Center (RNC) in Brookings, SD using Continental × British crossbred steers (initial shrunk BW = 381 ± 37.1 kg). This study used 6 replicate pens (24 total pens) of 7 or 8 steers assigned to one of three dietary treatments. Dietary treatments included: 1) DDGS fed at 20% DM (15.4% CP, 8% RDP, and 1.90% NPN; DDGS), 2) SBM replacing 50% of DDGS (16.4% CP, 9% RDP, and 0.96% NPN; SBM50), 3) SBM replacing 100% of DDGS (17.4% CP, 10% RDP, and 0.05% NPN; SBM100). The model included treatment and block (initial BW) as fixed effects; pen was the experimental unit. Treatment effects were evaluated for linear and quadratic components by the method of orthogonal polynomials. Whole blood was collected and harvested as sera on d 77, 105, and 139 to determine circulating concentrations of sera urea-N. On a live basis, feeding SBM linearly increased final BW ($P = 0.03$) but did not affect DMI ($P \geq 0.33$). Dietary treatment tended to affect ADG

(Quadratic; $P = 0.09$) and G:F (quadratic; $P = 0.06$) with the greatest positive effects in SBM50 fed cattle. Carcass adjusted final BW was calculated by dividing hot carcass weight (HCW) by a common dressing percentage of 0.625 (cFBW). No differences were noted for carcass adjusted final BW, average daily gain (ADG), dry matter intake (DMI), or feed efficiency ($P \geq 0.18$). Dietary treatment tended to affect G:F (quadratic; $P = 0.10$) and SBM increased the apparent efficiency of energy capture (Linear; $P = 0.01$). The total and partial substitution NEg values were 17.0 and 27.5% greater than DDGS respectively. Dietary treatment had no effect ($P \geq 0.22$) on HCW, rib fat, or marbling score. Complete replacement of DDGS with SBM linearly increased rib eye area (REA) by 1% ($P = 0.02$), but linearly decreased dressing percentage (DP; $P = 0.03$). Distribution of USDA quality or yield grades were unaffected by treatment ($P \geq 0.36$). Feeding SBM as a replacement of DDGS altered the distribution of liver scores. Steers from SBM100 had fewer livers classified as normal and a greater proportion of livers classified as severely (A+ or Greater) abscessed ($P = 0.05$). No treatment × day interaction was observed for sera urea-N ($P = 0.20$). However, day ($P < 0.01$) and treatment ($P < 0.01$) effects were observed. Throughout the duration of the trial the SBM100 treatment maintained greatest sera urea-N concentrations, the SBM50 treatment being intermediate, and the DDGS treatment had least concentrations of sera urea-N ($P < 0.01$). Further, sera urea-N concentrations increased overtime from d 77 to d 139 ($P < 0.01$). In this experiment, replacement of DDGS with SBM increased REA and tended to decrease DP and had a quadratic tendency to improve feed conversion with no other observed effects on carcass adjusted growth performance or carcass traits.

CHAPTER I: REVIEW OF LITERATURE

GENERAL INTRODUCTION

With present issues of environmental impact, global inflation, and rising feed prices, there has been recent pressure for producers to find more economically friendly feed sources for livestock (Suriyapha et al., 2022). An opportunistic solution is the utilization of agro-industrial by-products that are unable to be used for human consumption as alternative animal feeds (Faccenda et al., 2018). Alternative feed ingredients such as distillers co-products and soybean meal (SBM) present a favourable circumstance to beef producers. Soybean meal is a major feed ingredient for livestock species, specifically monogastric animals and dairy cattle. However, it has rarely been used in beef cattle diets in the last couple decades (Budi, 2020). Rather, distillers co-products have been used by reason of their preferable prices over soybean meal (Klopfenstein et al., 2008).

Because of increased research and economic factors, the ethanol industry has changed and evolved its production practices. These changes promote variability in nutrient composition and the feed value of distillers co-products to ruminants. In recent decades, ethanol production plants have discovered an economic opportunity with the extraction and sale of corn oil as a separate by-product. This has resulted in distillers co-products with reduced oil content (Espinosa and Stein, 2018). During ethanol production, one bushel of grain produces approximately 13 litres of ethanol and between 7.7 and 13.1 kilograms of DDGS (Harris, 2008). In 2015, ethanol production amounted to about 68 billion litres with DDGS being a major by-product (Bhadra et al., 2017). The average use of DDGS in the United States feedlot industry is 19.9% diet DM inclusion (Asem-Hiablie

et al., 2016). A 2015 consultant survey (Samuelson et al., 2016) indicated 70.8% of nutrition consultants chose to use wet distillers grains as the primary grain by-product in finishing cattle diets while 16.7% chose to use dried distillers grains.

Soybean is an important crop, providing protein for human consumption directly or indirectly through livestock products (Arnall et al., 2020). Since 2002, soybean production has increased with an 18% increase in acres planted, along with 30% greater yields because of better genetic varieties (Vaiknoras, 2023). When processed, one bushel of soybeans yields approximately 5 kg of oil and 21 kg of meal (Arnall et al., 2020).

Soybean meal composition is affected by the origin of the soybean and the processing conditions and methods used at the production plant (Budi, 2020). Despite these conditions, soybean meal nutrient composition often has reduced variability compared to distillers co-products (Fontaine et al., 2007). Currently, the price relationship between soybean meal and distillers co-products for use of animal feed is more attractive in regard to distillers co-products when evaluated on a cost per unit of protein. However, this price relationship is subject to change. Multiple soybean crushing plants are in construction in the United States due to a rise in soybean production and demand for biomass based biodiesel. Presently there are plants being constructed in Shell Rock, Iowa (Wilde, 2021), Casselton, North Dakota (Reidy, 2022), Montgomery County, Kansas (Neeley, 2021), and Mitchell, South Dakota (Kronaizl, 2022). With increased supply of soybean meal, the fate of the economic environment of soybean meal is projected to become more favorable to the livestock producer. As a result, this research is needed to determine the effects of the replacement of distillers grains with soybean meal on cattle performance.

PROCESSING OF FEEDSTUFFS

Soybean Meal Production

Three methods exist to extract oil from soybeans, with the most common being solvent extraction. The other two processes include mechanical extraction using a screw press (expeller) which results in an oil content of 5% in soybean meal, and the last method utilizes combination of both solvent and expelled extraction (Johnson and Smith, 2018). Solvent extraction results in the by-product soybean meal which contains approximately 1.5% oil (Heuzé et al., 2020). Industry standards for soybean meal is a minimum of 0.5% oil and maximum fiber content of 3.5% for high protein soybean meal (47.5 to 49% CP, as-is basis) and a maximum of 7% fiber for low protein soybean meal (44% CP, as-is basis) (Dunford, 2012).

The first few steps of soybean preparation are the same in both solvent extraction and expeller pressed soybean meal (Johnson and Smith, 2018). To prepare the soybeans for extraction, the soybeans are cleaned to remove foreign material which may be inhibitory to the extraction process or destructive to the facilities (Johnson and Smith, 2018). The whole soybeans are then dried to approximately 9.5% moisture to reduce oil viscosity, soften the grain, and denature enzymes that would otherwise decrease the quality of the final product (Dunford, 2012).

The beans are then passed through a rollermill with conjugated rollers to crack the beans and reduce size variability of the beans prior to processing (Johnson and Smith, 2018). In the production of high protein soybean meal, the beans are aspirated to remove the hulls of the soybean which are then passed over a gravity table to salvage smaller

dehulled soybeans (Johnson and Smith, 2018; Heuzé et al., 2020). Whereas in low protein soybean meal, the hulls which consist of approximately 8% of the original soybean, remain in the meal (Dunford, 2012).

During solvent extraction, the complete fraction of dehulled soybeans is then tempered or conditioned by heating to 65°C in rotating drums with indirect steam heating (Dunford, 2012). Conditioning of the soybeans by use of heat ensures proper cell rupture necessary for efficient extraction (Johnson and Smith, 2018). The heated and cracked soybeans are flaked by passing through a second rollermill with smooth rollers and transferred to either the expander or extractor (Johnson and Smith, 2018). Increasing surface area of the soybean during flaking increases contact between the solvent and the oilseed during solvent extraction. This increases the efficiency of solvent extraction therefore minimizing meal and oil quality deterioration (Dunford, 2012).

In recent years, soybean plants have adopted the practice of utilizing expanders prior to solvent addition to rupture the cell walls of the soybean and create a porous structure more ideal for oil extraction (Heuzé et al., 2020). The expander shreds the soybean material and injects steam to cook the proteins and starches. The material exits the expander at a temperature of 110°C where the water quickly evaporates leaving a porous structure of the soybean material (Heuzé et al., 2020). After further cooling, the soybean material is transferred to the extractor.

Upon entering the extractor, the solid matrix of the expanded flakes is diffused with hexane which solubilizes the lipid material forming a mixture called “micella” (Wang et al., 1995; Heuzé et al., 2020). The micella is then collected by utilization of baskets with perforated bottoms to allow the solvent and oil to drain off as it moves up an

elevator (Dunford, 2012). After extraction, the lipid portion of the material is further refined while the solid portion is conveyed to a desolventizer-toaster for heating and steaming to recover unseparated hexane and hexane vapors which will be recycled back to the extractor (Johnson and Smith, 2018; Dunford, 2012). The solid portion is then toasted prior to cooling and grinding to produce feed-grade soybean meal (Heuzé et al., 2020).

Production process of DDGS

Two processes currently exist in the production of ethanol from corn: wet-milling and dry-milling (Shad et al., 2021). In the U.S. approximately 90% of ethanol production originates from dry-milling, whereas wet mills contribute the remaining 10% to the market (Shad et al., 2021). The main reason for the imbalance between production practices in the industry is because of lower capital costs and smaller size of dry-milling plants, as well as a capacity for higher levels of production of ethanol (Shad et al., 2021). The major feedstuff product of dry-milling is distillers grains plus solubles, while wet-milling produces gluten feed and corn syrup (Kielb et al., 2017). Distillers co-products higher in moisture content are cheaper to produce, but are more difficult to transport and store, thus lowering their value (Kielb et al., 2017). Both types of processing require cereal grain selected based on starch content and market price of the selected grain (Shad et al., 2021). As well, grain must be purchased free of impurities such as ergot, fusarium, and vomitoxin which cannot be broken down during the process of ethanol production (Shad et al., 2021). During the production process, starch from the original grain is

completely utilized and extracted resulting in the concentration of impurities of the original grain three times higher in the distillers co-product (Kielb et al., 2017).

In a dry-milling ethanol plant, the ethanol is produced from corn starch, and the non-starch constituents of the grain create the dried distillers grains with solubles (Li at al., 2019). The whole corn kernels are ground by hammer mills to reduce the particle size of the grain into course powder to increase accessibility of the nutrients by microbes and enzymes during the fermentation process which increases the efficiency of ethanol production (Shad et al., 2021). This step also improves water penetration during the cooking process (Shad et al., 2021).

The resulting flour meal is then mixed with water to form a mash and heated to 40 to 60°C in the pre-mixing tank (Shad et al., 2021). The mixture is then cooked at temperatures between 90-165°C (average 120°C) in a jet cooker to reduce bacteria levels prior to fermentation (Shad et al., 2021; Shad et al., 2021). The heat is then reduced to 60°C for 30 minutes during the liquefaction phase and heat stable α-amylase is added to the mash to hydrolyze long chains of starch to dextrose and glucose resulting in a lower viscosity medium (Shad et al., 2021; Shad et al., 2021). Ammonia is also added to the mixture as a buffer and nutrient to the yeast during fermentation (Shad et al., 2021).

To increase efficiency in the next phases, saccharification and fermentation are completed simultaneously (Newkirk, 2011). During saccharification, dextins are converted into simple sugars: glucose and maltose (Kielb et al., 2017). In the fermentation step, conditions are set at 33°C and a pH of 4.0 for 48 to 72 hours to allow sugars to efficiently be converted to alcohol by yeast (Kielb et al., 2017). In this step, one molecule of glucose is converted to two molecules of carbon dioxide and two molecules

of ethanol (Kielb et al., 2017; Tamang and Aryal, 2023). Preventing microbial cross contamination is crucial during fermentation to avoid decreases in ethanol production, specifically with lactobacilli which produces lactic acid inhibiting sulfur production (Shad et al., 2021).

The resulting “beer” product contains approximately 12.5% ethanol by total volume (Shad et al., 2021). The fermented “beer” is pumped into a multi-column distillation system where the solid and liquid phases are separated with the use of decanters (Newkirk, 2011; Kielb et al., 2017). The liquid phase is then evaporated and condensed to form the condensed distillers soluble (CDS) which is mixed with the solid phase (Shad et al., 2021; Kielb et al., 2017). The CDS is made up of large amounts of fat, minerals, water, soluble sugars, proteins, and organic acids (Shad et al., 2021).

The resulting medium is centrifuged to separate the liquid components of the stillage from the solid components (Newkirk, 2011). The liquid components are then further centrifuged to remove the corn oil to be marketed separately because of market demand and economic advantage for the ethanol plant (Shad et al., 2021). In early days of ethanol production, oil content of DDGS was as high as 14% (Shad et al., 2021). However, by 2014, approximately 85% of ethanol plants adopted oil removal techniques (Ribeiro et al., 2016) resulting in DG products having as low as 2.7% oil on a DM basis (Sounders and Rosentrater, 2009). The products of the further centrifuged liquid component and the solid components are then dried and granulated to create dried distillers grains plus solubles (Kielb et al., 2017; Shad et al., 2021).

Maillard Reaction

The Maillard reaction (MR) is a result of temperature and duration of thermal processing of feed products when proteins are in the presence of reducing compounds such as sugars (Teodorowics et al., 2018). Comparable results have been observed in terms of the extent of the MR with long-term thermal processing undergoing low temperatures and high temperature thermal processing (Teodorowicz et al., 2018). This heat damage decreases protein degradability in the rumen and the bioavailability of amino acids to the host animal.

For the Maillard reaction to occur, a nucleophilic amino group ($-NH_2$) of amino acids and reactive carbonyl groups (free aldehyde or ketone) of sugars have to be present (Oba et al., 2022). The Maillard reaction takes place in three general steps (Awoyinka, 2014). Initially, a condensation reaction takes place between the carbonyl groups and the amino groups (Kutzli et al., 2021). This produces N-substituted glycosylamine and water which then goes through Amadori rearrangement forming aminoketose (Awoyinka, 2014). Aminoketose molecules provide the substrate for the third step to proceed and for Maillard reaction products (MRP) (Zhang et al., 2009). Furthermore, under conditions of higher pH, the amino group increases in nucleophilicity and is more likely to react with the reducing sugar causing the Maillard reaction to occur at greater frequency (Lofty et al., 2021).

The quality of protein often depends upon the amino acid digestibility and its ability to be utilized by the animal (Teodorowicz et al., 2018). Corn processing by-products such as distillers grains are often subject to differing extents of the MR from

plant to plant resulting in variability in feedstuff quality and composition (Fontaine et al., 2007). During processing of corn by-products, incomplete fermentation and starch removal causes residual sugars allowing for greater extent of MRPs in the final commodity (Fontaine et al., 2007). As the degree of heat damage and MRPs increases, the fraction of crude protein unavailable to rumen degradation also increases (Jacob et al., 2022). Dahlke et al., (2013) reported *in vitro* true DM disappearance of distillers grains decreased from 98.4, 88.0, 75.7, and 54.2% for normal, mild, moderate, and extreme heat damage, respectively.

The most important consequence of the Maillard reaction is the impairment of the biological availability of lysine by cross-linkages (Teodorowicz et al., 2018). While other amino acids are susceptible, lysine is the most vulnerable due to the presence of two amino groups rather than one which offer binding sites for reducing sugars (Teodorowicz et al., 2018). This cross-linking renders the amino acid biologically unavailable to the animal, thus decreasing the digestibility of dietary crude protein (Teodorowicz et al., 2018).

In a study completed by Fontaine et al. (2007), soybean products and DDGSs were tested to determine total available lysine. Eighty-four samples of soybean meals and soybeans, and 80 samples of corn DDGSs obtained across the United States were utilized. Their results demonstrated that the soy products had higher levels of available lysine than the DDGS samples. As well, upon further thermal processing, lysine as a percent of crude protein in the soy products decreased by a lesser degree than that of the DDGS. Fontaine et al. (2007) theorized this was because of the sugar content of the DDGS samples.

NITROGEN UTILIZATION OF RUMINANTS

Rumen nitrogen and microorganisms

Protein in the ruminant animal serves as a feed source to both the animal and the rumen microorganisms (Putri et al., 2021). The components of the cell wall of microbes require ammonia from protein degradation and the microbes provide amino acids and peptidases to the animal (Putri et al., 2021). Approximately half of the microbial mass of the rumen is attributed to bacteria, yet bacteria contributes the majority of microbial protein flow to the duodenum (Getabalew and Negash, 2020). Protozoa account for the second largest microorganism population in the rumen at approximately 20-50% of microbial mass (Getabalew and Negash, 2020). However, the contribution of protozoa to protein breakdown is relatively low.

Protein breakdown is performed by all rumen microbes at differing extents (Getabalew and Negash, 2020). Seventy to 80% of ruminal microorganisms attach to ingested feed particles in the rumen, while the remaining microorganisms remain free within the rumen fluid (Bach et al., 2005). Rumen microbes secrete enzymes such as protease, peptidase, and deaminase to degrade protein nitrogen from oligopeptides into tri- and dipeptides, amino acids, ammonia, and volatile fatty acids (Putri et al., 2021; Owens et al., 2014; Getabalew and Negash, 2020). This proteolytic activity as well as protein type play a large role in the extent and rate of protein degradation (Bach et al., 2005).

Peptides and amino acids can be absorbed by the microbial cell and the availability of energy in the form of carbohydrates influences the fate of absorbed

peptides and amino acids in the microbial cell (Bach et al., 2005). Amino acids will be transaminated or used for microbial protein synthesis if energy is readily available (Bach et al., 2005). This microbial protein will flow through the gastrointestinal tract (GIT) and be absorbed as peptides and amino acids in the small intestine (Putri et al, 2021). In the case that energy is limited, the amino acids will be deaminated into ammonia and their carbon skeleton will be fermented into volatile fatty acids (Bach et al., 2005).

Urea Recycling

The evolutionary advantage of ruminant animals to recycle N to the rumen aids the animal during periods of protein deficiency through an absorbable protein supply (Reynolds & Kristensen, 2008). The recycling provides a vital source of N for microbial protein synthesis within the rumen (Souza and White, 2021). Ureolytic bacteria in the rumen produce catalytic ureases responsible for the rapid breakdown of ingested non-protein nitrogen (NPN) into ammonia (NH_3) and carbon dioxide. Ammonia in the rumen is partially used by rumen bacteria as substrate for microbial protein synthesis. However, the rate of hydrolysis of NPN to ammonia is much greater than the rate of ammonia utilization by rumen bacteria. Therefore, the excess ammonia is transported mainly across the rumen epithelium but can also be transported across the small intestinal mucosa, and large intestinal mucosa to a lesser extent. The absorbed ammonia is transported to the liver via the portal vein. Approximately 70 to 95% of ammonia can be extracted by the liver to be detoxified for conversion back to urea (Getahun et al., 2019).

The urea cycle in the liver is responsible for the conversion of NH_3 back to urea in its less toxic form (Salim et al., 2015). The enzymes involved in the urea cycle are

influenced by the nutrition factors of the ruminant diet. Salim et al. (2015) reported increasing dietary DDGS and MDGS inclusion from 0 to 50% diet DM linearly increased the activity of urea enzymes. Along with an increase in the activity of urea enzymes, concentrations of sera urea-N proportionally increased. The animals used in the study had adapted to an increase of N in the diet by responding with increased urea cycle enzyme activity. In an earlier study, Elsasser et al. (1996) reported that increasing the crude protein of the diet significantly increased arginase activity, liver weight, and total urea production, indicating ruminant's ability to compensate and adapt to higher blood N.

Urea produced in the liver will be recycled back into the gastrointestinal tract (GIT) directly or indirectly by salivary secretions or excreted through the kidneys. Salivary secretion of urea is highly influenced by diet type. Rumination stimulated by high-roughage diets increases the flow of salivary secretions to the rumen (Getabalew and Negash, 2020). Approximately 10 to 40% of urea-N entry into the rumen can be contributed from salivary flow, however the majority of urea enters the GIT through the rumen epithelium (Getahun et al., 2019). Urea from the liver is carried across the rumen wall by transporters to be hydrolyzed back into ammonia for microbial protein synthesis (Getabhun et al., 2019). Between 27 and 60% of total urea production by the liver will enter the rumen by salivary secretions or through the rumen epithelium directly (Keonig et al., 2000). In the case of high levels of degradable protein in the rumen, the ammonia concentration in the rumen creates low ruminal urease activity which decreases urea transfer from the blood to the rumen (Getabalew and Negash, 2020), thus increasing the amount of urea excreted in urine via the kidneys.

Protein Digestion in the Small Intestine

Protein entering the small intestine is comprised of ruminally undegradable protein, ammonia, urea, endogenous protein, and microbial protein which combined form metabolizable protein (Swanson, 2019; Getabalew et al., 2020). Rumen undegradable protein that escapes the rumen environment and microbial protein mixes with pancreatic enzymes, pepsin, and HCl in the abomasum to be digested in the small intestine (Pérez-Barbería, 2020). The acidic environment of the abomasum breaks down microbial cells to release microbial protein which flows through the pyloric sphincter into the small intestine (Swanson, 2019). The pancreas releases proteases, trypsin and chymotrypsin, into the duodenum to begin protein digestion in the small intestine (Swanson, 2019). Proteases facilitate the hydrolysis of large polypeptides to smaller peptides which are further hydrolyzed by mucosal peptides to amino acids and small peptides (Alpers, 1994).

In ruminants, 65 to 75% of duodenal flow of N compounds is estimated to be readily digestible in the duodenum (Owens and Zinn, 1988). Further, the digestive capacity for protein in the jejunum and ileum is high, particularly in regard to the absorption of L-form amino acids (Pérez-Barbería, 2020). Concurrently, approximately 80% of duodenal crude protein supply is available to the host animal as amino acids (NASEM, 2016). Knowledge is scarce regarding intestinal degradability of individual amino acids and their postabsorptive utilization limiting the efficiency of defining amino acid requirements (Mjourn et al., 2010). Amino acids digested in the small intestine can either be used as building blocks for protein synthesis, metabolized to glucose, or converted to urea and CO_2 (Pérez-Barbería, 2020).

PROTEIN REQUIREMENTS OF RUMINANTS

Crude Protein

In nonruminants, protein requirements are based on supply and digestibility of amino acids, whereas ruminants are much more complex. The microbiome of the rumen introduces a myriad of interactions between pre- and post-rumen absorption, influencing host metabolism and growth. Defining the crude protein requirement for ruminants is a challenging task because of remodeling of protein and amino acids in the rumen by microflora and the variety and variability of feedstuffs (Lapierre et al., 2006). Crude protein is a measure of the nitrogen content of a feedstuff including both true protein and non-protein nitrogen. The calculation of crude protein is the nitrogen content multiplied by the conversion factor of 6.25, assuming that the average nitrogen content of protein is 16% and all nitrogen is protein bound. However, this leads to inaccuracies in feed formulation as feedstuffs differ in amino acid profile and a wide range of other compounds in feedstuffs contain nitrogen, such as nitrates, ammonia, urea, nucleic acids, and alkaloids (Mæhre et al., 2018). Furthermore, nutrients reaching the post-ruminal environment differ from those present in the diet, making prediction of crude protein and amino acid requirements difficult (Lapierre et al., 2006). This difference in composition of nutrients is because of pregastric fermentation in portions of the ruminant's four compartment stomach (rumen, reticulum, and omasum) resulting in the production of volatile fatty acids and microbial biomass (Harmon and Swanson et al., 2019; Swanson et al., 2019). Therefore, simple addition of amino acids to the diet is not an efficient option to increase amino acid flow to the duodenum as free amino acids are rapidly degraded in the rumen (Lapierre et al., 2006). To manage these challenges, crude protein is divided

into segments of degradability, rumen undegradable protein (RUP) and rumen degradable protein (RDP) and microbial protein. This system was created to better define protein requirements of ruminant animals (Burroughs et al., 1975). This being considered, the six factors commonly used to determine the quality of protein for feedstuffs include: amount of CP, degradation of protein in the rumen, urea recycling ability, microbial protein synthesis, digestibility in the small intestine, and utilization of microbial protein (Tedeschi et al., 2015).

Protein Degradability Classification

Crude protein in feedstuffs includes both non-protein nitrogen and true protein (Schwab et al., 2003). Non-protein nitrogen includes smaller molecules such as peptides, free amino acids, nucleic acids, amides and amines, nitrate, and ammonia which are highly degradable (Schwab et al., 2003). True protein includes the large molecules present in cell walls and cell contents of plant and animal tissues (Schwab et al., 2003).

Crude protein content of feedstuffs is sorted into three fractions: A, B, and C (NASEM, 2016). The A fraction refers to the rapidly degradable fraction of non-protein nitrogen compounds (NASEM, 2016). The fraction B refers to true protein which is potentially undegradable and is subdivided into B1 (soluble true protein), B2 (non-cell wall), and B3 (available cell wall protein), with differing levels of degradability (NASEM, 2016; Tedeschi et al., 2015). The degradability of fraction B in the rumen depends upon the competing rates of degradation and the passage rate of undigested feed from the rumen (Schwab et al., 2003). Therefore, fraction B can be both degradable and undegradable in the rumen. The C fraction of crude protein refers to protein largely

unavailable in the rumen and is slowly degraded or completely undegradable, such as Maillard protein, lignin, and tannin bound protein (Das et al., 2015; NASEM, 2016).

Metabolic and Microbial Protein

The metabolizable protein system was developed to establish a clearer understanding of the protein requirements of ruminants (Owens et al., 2014; Watson et al., 2017). Rumen degradation of dietary protein, as well as the separate needs of the rumen organisms and the host animal, are considered with the metabolizable protein system (NASEM, 2016). The three fractions of metabolizable protein entering the duodenum are derived from endogenous protein, rumen undegradable protein, and microbial protein (NASEM, 2016). The components of these fractions, which contribute to the metabolizable protein supply, are the components which are digested as amino acids within the small intestine and absorbed (Owens et al., 2014).

Adequate rumen degradable protein is necessary for maximizing microbial protein synthesis as it provides peptides, amino acids, and ammonia as substrate for the rumen microbiome (NASEM, 2016). Approximately 85% of ruminally degradable protein is available for synthesis of microbial protein and approximately 50% of all protein digested in the small intestine is supplied by microbial protein and used by the beef animal (Schwab et al., 2003; Harmon and Swanson, 2019). Depending upon the protein degradability in the diet, microbial protein can displace the need for essential amino acids in the diet by synthesizing amino acids in the rumen (Owens et al., 2014). Because of the high proportion of CP supply to the ruminant being dependant upon microbial protein, maximizing microbial protein yield flowing to the small intestine is

essential (Owens et al., 2014). In addition, increasing the amount of RDP captured in the rumen by microbial cells improves the supply of amino acids to the small intestine and decreases N losses (Bach et al., 2005).

The first limiting factor of the microbial protein supply to the ruminant when grains are more extensively processed is the amount of dietary RDP and the availability of ammonia to the rumen microbiome (Schwab et al., 2003; Owens et al., 2014). Under most conditions, quantity of carbohydrate or organic matter fermented in the rumen increases the microbial load leaving the rumen (Bach et al., 2005). Microbial yield is increased as the amount of energy fermented in the rumen increases to supply the rumen microbes with energy for maintenance and growth to synthesize necessary peptide bonds (Bach et al., 2005; Owens et al., 2014). However, when the rate of carbohydrate fermentation exceeds the rate of protein degradation, microbial protein synthesis often decreases (Bach et al., 2005). As confirmed by Owens et al. (2014), efficiency of microbial protein synthesis is inversely related to grams of ruminally digested starch and grams of ruminally digested non starch organic matter; efficiency of microbial protein synthesis is positively related to DMI as a percentage of BW and diet CP concentration (Owens et al., 2014). Furthermore, as DMI increase, the rumen retention time decreases, and the amount of energy needed for maintenance by the rumen microbes decreases. This reduces bacteria lysis, and bacteria predation by protozoa, increasing microbial efficiency (Bach et al., 2005; Owens et al., 2014).

Protein and Energy Synchronicity

The synchronicity between energy and protein degradation in the rumen is a very important factor in the optimization of microbial protein synthesis (Arias et al., 2020). Ruminal synchrony of protein and energy digestion improves ruminal fermentation, microbial protein synthesis, and digestibility of nutrients (Sinclair et al., 1993; Cole and Todd, 2008). If protein degradability exceeds that of carbohydrates entering the rumen, ammonia may accumulate and be absorbed into the body to be excreted in urine (Seo et al., 2012), resulting in inefficient utilization of protein and NPN. Often, RDP is supplied in finishing diets by urea because of cost effectiveness. However, urea is highly soluble in the rumen, potentially leading to asynchronization of fermentable energy availability and ammonia production in the rumen, negatively affecting microbial protein synthesis (Salami et al., 2021). Whereas plant proteins such as soybean meal degrade at a constant and continual rate within the rumen, peaking three to five hours post feeding (Owens and Zinn, 1988).

A deficiency in RDP may cause decreased volatile fatty acid yield from carbohydrate fermentation, decreasing the energetic efficiency of the diet (Russel et al., 1992), potentially leading to reduced performance of finishing cattle even when metabolizable protein requirements have been met through RUP (Cooper et al., 2002). Optimal RDP levels correspond to synchronicity of protein and energy availability, thus RDP requirement differs with grain processing method. Slower fermenting carbohydrates require smaller amounts of dietary RDP, whereas ruminal fermentation is benefited by greater RDP when carbohydrates are fermented quickly in the rumen. Across corn processing methods, theoretical dietary RDP requirements for finishing cattle are 6.3 to

6.8% for dry-rolled corn-based diets (NASEM, 1996; Cooper et al., 2002), approximately 8.3% for steam-flaked corn-based diets (Cooper et al., 2002; Gleghorn et al., 2004; Wagner et al., 2010), and 10.1% for high-moisture corn-based diets (Cooper et al., 2002).

Amino acids

With the remodeling of nutrients in the rumen, amino acid supply is difficult to quantify. The quality of dietary proteins is dependant on their ability to be absorbed and their efficient use for protein synthesis to meet the requirement for ruminants (Teodorowicz et al., 2018). Both the quantity, quality, and proportionality of the available amino acids are vital to achieve maximum average daily gain (NASEM, 2016). Amino acid requirements for ruminants are dependent upon needs for production and needs for maintenance (Owens et al., 2014). During stages of high productivity, meeting amino acid requirements becomes imperative (Hijar et al., 2020).

Amino acid requirements for tissue growth in growing and finishing cattle is a function of the proportion of individual amino acids in body protein accretion and therefore is dependant upon predictions of retained protein (NASEM, 2016). Table 1.1 details the quantity of amino acids contained in the empty body protein (EBP) of the beef animal. Net daily synthesis of protein represents a balance between the breakdown and resynthesis of body protein (NASEM, 2016). In a 500 kg finishing steer, the daily accretion of protein is approximately 150 g (NASEM, 2016). Whereas, the daily anabolism and catabolism of body protein is approximately 2550 g, denoting the daily accretion of body protein at this stage of production to be only about 5.5% of total body protein flux (NASEM, 2016). To accurately determine retained amino acids, many

factors must be considered including prediction of microbial growth and composition, amount and composition of dietary undegradable protein, intestinal digestion and absorption, and accretion of absorbed amino acids into tissue (NASEM, 2016).

In cattle, increasing post-ruminal flow of protein aids in post-ruminal starch digestion (Swanson, 2019). Previous studies in ruminants completed by Yu et al. (2013) indicate that phenylalanine and leucine can up-regulate pancreatic alpha-amylase secretion in the proximal small intestine which tended to increase small intestine starch digestion in steers. However, studies also show ruminal bacteria have difficulty synthesizing phenylalanine, leucine, and isoleucine (Bach et al., 2005). As a result, the need for rumen degradable protein increases as grain is more extensively processed and the extent of carbohydrate digestion and absorption increases to support the rumen microbiome (Owens et al., 2014).

With the ruminant's unique ability to utilize microbial protein, ruminants can partially or completely displace the need for essential amino acids in the diet. However, during periods of high productivity or with a goal of maximum gain, supplementation with protein sources which provide essential amino acids will increase production (Owens et al., 2014). Based on swine studies, diets with high proportions of maize products are low in lysine and tryptophan (Owens et al., 2014). Therefore, in high concentrate diets lysine is generally the first-limiting amino acid followed by methionine; both of which are essential to muscle synthesis (Baggerman et al., 2021). Furthermore, lysine is a growth limiting amino acid for rumen bacteria (Bach et al., 2005), potentially leading to reduced rumen bacteria growth under circumstances of increased Maillard

proteins. However, for high production, forage-fed beef cattle, methionine has been theorized to be the first-limiting amino acid (Hijar et al., 2020).

In a study done by Xue et al. (2011), the effects of rumen protected lysine supplementation were analysed utilizing 56 Limousin-cross bulls in an 84-d growth trial. The bulls were fed a maize-based diet and the treatments consisted of rumen protected lysine fed at levels of 0, 5, 10, or 15 g/hd/d. Lysine supplementation did not alter DMI, but increased feed efficiency and ADG, with the greatest effect achieved at 10 g/hd/d of rumen protected lysine. They also observed that supplementing lysine decreased plasma urea nitrogen, suggesting the rumen protected lysine was effectively utilized for tissue growth. In a study completed by Baggerman et al. (2021), 128 crossbred steers were utilized to evaluate the effects of rumen protected methionine in feedlot cattle. Steers were supplemented with 0, 4, 8, or 12 g/hd/d of encapsulated methionine for 111 or 139 d. There was a tendency for an increase in ADG during the final 28 d, although there was no significant difference in live cattle performance over the duration of the entire trial. However, supplementation with rumen protected methionine increased longissimus muscle (LM) area by 9% when cattle were fed 12 g/hd/d.

Inhuber et al. (2021) designed a study to evaluate the effects of supplementation of rumen protected methionine in a CP deficient diet on growth performance of 69 Fleckvieh bulls for an average of 105 d. The treatments consisted of a control diet containing 13.7% CP and 2.11 g methionine/kg diet DM, and three diets deficient in protein (9.04% CP), with two treatments containing differing levels of methionine (2.54 g/kg DM and 1.56 g/kg DM). The diets containing reduced CP also contained rumen protected lysine at 2.7 g/kg DM. Growth performance and carcass weights were reduced

in the CP reduced diets. They also reported serum methionine concentrations were increased in supplemented diets, however, this was not reflected in bull growth performance. Serum lysine concentrations were decreased in the reduced CP diets despite additional supplementation, indicating lysine to be the first-limiting amino acid for growth.

Liver Abscess and Lysine Connection

Liver abscesses occur in every age and type of cattle. However, the production stage in which liver abscesses cause the greatest economic disturbance is in feedlot cattle (Nagaraia and Lechtenberg, 2007). In North America, aggressive feeding programs are linked to increased incidence of liver abscesses in feedlot cattle at slaughter (Aguiar Veloso and Drouillard, 2020). Altogether, the estimated annual loss to the beef industry due to liver abscesses in cattle is $7,007,797 (Aguiar Veloso and Drouillard, 2020) ranging from $8 to $189 lost revenue per animal based on carcass losses (Lawrence, 2022). This economic impact is multi-faceted. Liver abscesses result in decreased line speed at commercial abattoirs, decreased carcass yield, and suboptimal animal performance, thus decreasing monetary gains in the beef industry (Aguiar Veloso and Drouillard, 2020). Animals with abscessed livers also can have decreased feed intake, weight gain, feed efficiency, and dressing percent (Nagaraia and Lechtenberg, 2007). Depending on the severity of the liver abscess, effects on the previously mentioned variables can range from zero to up to 11% decreases in average daily gain and a depression in feed efficiency up to 9.7% (Nagaraia and Lechtenberg, 2007).

Many etiological agent species have been identified in liver abscesses with the primary bacteria flora being *Fusobacterium necrophorum* (Nagaraja and Lechtenberg, 2007). High grain concentration in the diet increases the incidence of acidic environments in the rumen which damages the rumen wall and allows *F. necrophorum* to migrate from the rumen via portal blood to the liver where abscesses are formed (Russell, 2005). *F. necrophorum* is a gram-negative, anaerobic, nonsporulating, and rod-shaped bacterium that uses lactate as the preferred energy source and tends to increase 10-fold in cattle fed high grain diets (Schwarz et al., 2023; Aguiar Veloso and Drouillard, 2020). Along with lactate, research suggests *F. necrophorum* can utilize lysine as a source of energy for growth (Russell, 2005). Russell (2005) described *F. necrophorum's* ability to degrade lysine in the rumen while in another study conducted in vitro by Elwakeel et al. (2013), it is suggested that lysine may be the preferred energy substrate for the bacteria.

A study conducted by Aguiar Veloso et al. (2018) utilized 384 beef steers supplemented with four levels of rumen protected lysine at 0, 20, 40, and 60 g/head/day during the last 42 days of the finishing period. As incremental amounts of lysine were added to the diets, liver abscess severity tended to increase as well as number of affected animals with the animals fed the highest amount of lysine supplementation having the greatest percentage of severely abscessed livers. Furthermore, they discovered a linear increase in body weight with increasing lysine supplementation, yet a linear decrease in hot carcass weight. This decrease was proposed to be a consequence of increased carcass trimming at time of slaughter. This study also suggested the possibility of proliferation of *F. necrophorum* in the post-ruminal GIT after observations of increased liver abscess incidence with rumen protected lysine.

VALUE OF SOYBEAN PRODUCTS COMPARED TO DISTILLERS PRODUCTS IN FINISHING DIETS

Compared to dairy cattle and monogastric animals, the value of soybean meal compared to other protein sources has been less studied in finishing cattle in the last couple decades. This is caused by the favourable price of distillers grains (DG) products over soybean meal. Finishing cattle have the ability to utilize DG products readily, making the price/nutrient value more ideal in relation to other protein sources. Nonetheless, there is a possibility of soybean meal resulting in equal or better animal performance when fed to finishing cattle.

In studies with small ruminants there have been mixed results when comparing the effects of feeding DG products and SBM. In a finishing Boer goat trial when SBM was compared to DDGS, the DDGS treatment resulted in greater ADG and improved feed:gain compared to the SBM treatment with no observed differences for carcass characteristics (Sorenson et al., 2021). Although, in a finishing lamb trial examining the differences in growth performance and carcass characteristics between SBM and DDGS done by Huls et al. (2006), there were no differences in growth performance, DMI, or carcass outcomes between treatments. Dried distillers grains was compared to SBM in another growing and finishing lamb trial to analyse their effects on digestibility and rumen ecological niches (Shen et al., 2020). No differences were observed between bacterial communities within the rumen ecology between treatments in this trial. However, it was reported that protozoa populations were reduced in the DDGS treatment. The reason for this decrease in protozoa populations in the rumen was not specified in

that experiment, but Faccenda et al., (2018) may have discovered an explanation in a large ruminant digestibility trial analysing the differences between dried brewers grains (DBG) and SBM. They utilized four canulated Jersey oxen in a 4 x 4 latin square design with four treatments of DBG replacing SBM at levels of 0, 33, 66, and 100%. They reported a quadratic effect in rumen ammonia nitrogen concentration with the maximum level occurring at 36.7% DBG. At 0 and 100% DBG inclusion there was a concentration of 9.5 and 6.79 mg/100mL ammonia nitrogen in the rumen with the maximum at 36.7% with 9.95 mg/100mL, respectively. In this study the replacement of soybean meal with ethanol co-products reduced TDN intake but did not alter DMI or ruminal pH. As well, dry matter and non-fibre carbohydrate digestibility decreased linearly with increasing ethanol co-product inclusions.

Pittaluga et al. (2021) compared performance and carcass attributes of cattle fed SBM and DDGS in combination with two levels of non-roughage NDF (NRFC). Steers fed high NRFC and DDGS as a protein source tended to have poorer feed conversion than both treatments of SBM fed in combination with high and low NRFC. Soybean meal fed calves had greater final body weight and tended to have greater ADG compared to steers fed DDGS. Protein source did not affect HCW, ribeye area (REA), dressing percent, ribfat (RF), or marbling score. In an earlier study, Mateo et al., (2004) analysed the growth performance, and carcass trait effects of calves fed DDGS and wet distiller grains plus solubles (WDGS) in replacement of SBM. No differences were observed between the control diet containing SBM and the distillers grains treatments for growth performance effects. However, cattle fed distillers co-products had greater RF and yield grades with no other differences in carcass attributes.

Ruminal degradation of the CP content of SBM and DG products is reported at a wide range of values between and within these groups of feedstuffs. Mjourn et al. (2010) reported ruminal degradation of CP is greatest in solvent extracted SBM and MDGS compared to expeller pressed SBM and dried DG products (Mjourn et al., 2010). This is largely caused by differences in processing techniques and the higher temperatures subjected to the latter group. Similar results were reported in a digestibility trial completed by Schumacher et al. (2020). They observed similar results between expeller pressed SBM and DDGS; MDGS was not included in this study. Rumen undegradable protein content of both expeller pressed SBM and DDGS were 60.0 and 59.9% of total CP respectively. The RUP digestibility however did differ, with expeller pressed SBM RUP being 98.7% digestible and DDGS RUP being 93.5% digestible. The RUP content of solvent extracted SBM was 27.3% of total CP at 98.5% digestible.

The variability in nutrient value of DG products, particularly with DDGS, can be a source of uncertainty for livestock feeders, whereas this is less of a concern regarding SBM (Hoffman and Baker, 2011). Mjourn et al. (2010), compared the nutrient values of SB products and DG products to the current values provided by NASEM (2000). They reported that the CP of the SB products were comparable to NASEM values (2000), and NDF and ADF being slightly less than reported values. However, DG product nutrient values were much more variable with CP ranging from 29.7 to 41.5%, 24.5 to 42.5% for NDF, and 3.2 to 12.8% for EE. In regard to ether extract, samples were taken from plants removing excess oil from the DG products and plants that did not. Table 1.2 highlights current nutrient composition of SBM and DG as indicated by the NASEM (2016).

Another concern in respect to DDGS is sulphur content. During the production of ethanol, sulfuric acid is added to the end the process of fermentation, increasing the sulphur levels of the DG products compared to the originating grain (Stewart, 2017). As a result, DDGS inclusion can lead to excessive levels of sulphur in the diet, especially when animals consume water high in sulphates (Buckner et al., 2007). The threshold for sulphur inclusion in finishing diets is 0.4% diet DM, if exceeded, polioencephalomalacia, a potentially fatal neurological disease, can occur (Amat et al., 2014).

CONCLUSION

In summary, this review discussed the role and requirements of protein in the diet of ruminants. Estimating protein requirements for ruminant animals is complicated due to pregastric fermentation, where the amino acid profile of rumen degradable protein is modified by rumen microorganisms. Therefore, understanding the factors of protein quality are important for meeting protein requirements of the finishing beef animal. Protein quality is determined by the amount of CP, ruminal degradation of protein, urea recycling ability, microbial protein synthesis, digestibility in the small intestine, and efficiency of utilization of microbial protein.

This review also highlighted the rise in agro-industrial production driving an increase in protein by-products unable to be used for human consumption. Thus, providing opportunities in alternative protein sources for feedyard operators. Processing techniques involved in the production of these by-products greatly impacts the quality of these proteins and their subsequent degradability within the rumen by microorganisms. Consequently, distillers co-products contain a greater concentration of rumen

undegradable protein than that of soybean meal. Typically, distillers co-products are used in finishing cattle diets in the United States, motivating the cultivation of significant research and exploration of the effects of these protein sources in feedlot rations. Whereas the lack of diet inclusion of soybean meal has resulted in limited research on its effects in finishing cattle diets.

LITERATURE CITED

Aguiar Veloso, V., Drouillard, J. S. 2020. On the Potential Role of Dietary Lysine as a Contributing Factor in Development of Liver Abscesses in Cattle. Frontiers in Veterinary Science. **7**: 576647–576647. Doi: 10.3389/fvets.2020.576647

Aguiar Veloso, V., Van Bibber-Krueger, C., Horton, L., Karges, K., Drouillard, J. 2018. 255 Effects of Ruminally-protected Lysine on Performance and Carcass Characteristics of Finishing Cattle. Journal of Animal Science, **96**(3): 86–86. Doi: 10.1093/jas/sky404.190

Alpers, D.H., 1994. Digestion and absorption of carbohydrates and proteins. Physiology of the Gastrointestinal Tract. **1**(4**)**: 1723-1749.

Amat, S., McKinnon, J. J., Simko, E., Hendrick, S. 2014. Evaluation of feeding corn or wheat dried distillers' grains with solubles on animal health of finishing feedlot steers. Canadian Journal of Animal Science, **94**(3): 525-531. Doi: 10.4141/CJAS2013-182

Arias, R. A., Guajardo, G., Kunick, S., Alvarado-Gilis, C., Keim, J. P. 2020. Effect of Two Nutritional Strategies to Balance Energy and Protein Supply in Fattening Heifers on Performance, Ruminal Metabolism, and Carcass Characteristics. Animals (Basel). **10**(5); 852. Doi: 10.3390/ani10050852

Arnall, B., Baughman, T., Damincone, J., Lofton, J., Royer, T., Warren, J. 2020. Soybean Production Guide [Online] Available: https://extension.okstate.edu/fact-sheets/soybean-production-guide.html [2023 Sept. 15]

Awoyinka, B. O. D. 2014. A Study of the Maillard Reaction in Dried Distillers Grains for Use in Polymeric Materials. ProQuest Dissertations Publishing

Bach, A., Calsamiglia, S., Stern, M. D. 2005. Nitrogen Metabolism in the Rumen. Journal of Dairy Science, **88**(13): E9-E21. Doi: 10.3168/jds.S0022-0302(05)73133-7

Baggerman, J. O., Thompson, A. J., Jennings, M. A., Hergenreder, J. E., Rounds, W., Smith, Z. K., Johnson, B. J. 2021. Effects of Encapsulated Methionine on Skeletal Muscle Growth and Development and Subsequent Feedlot Performance and Carcass Characteristics in Beef Steers. Animals (Basel). **11**(6) : 1627. Doi : 10.3390/ani11061627

Bhadra, R., Rosentrater, A., Muthukumarappan, K. 2017. Modeling distillers dried grains with solubles (DDGS) mass flow rate as affected by drying and storage conditions. Cereal Chemistry. **94**(2): 294-309. Doi: 10.1094/CCHEM-04-16-0114-R

Buckner, C. D., Mader, T. L., Erickson, G. E., Colgen, S. L., Karges, K. K. and Gibson, M. L. Optimum concentrations of dry distillers grains with solubles for finishing beef steers. Nebraska Beef Report. 2007. **MP90**: 36–38.

Budi, T. 2020. Nutrient content of soybean meal from different origins based on near infrared reflectance spectroscopy. Indonesian Journal of Animal Science. **93**(10): 2567-2577. Doi: 10.3382/ps.2014-04068

Burroughs, W., Nelson, D. K., Mertens, D. R. 1975. Protein physiology and its application in the lactating cow: the metabolizable protein feeding standard [Feeds, amino acids]. Journal of Animal Science, **41**(3), 933–944. Doi: 10.2527/jas1975.413933x

Cole, N. A., Todd, R. W. 2008. Opportunities to enhance performance and efficiency through nutrient synchrony in concentrate-fed ruminants. Journal of Animal Science, **86**(14), E318–E333. Doi: 10.2527/jas.2007-0444

Cooper, R. J., Milton, C. T., Klopfenstein, T. J., Jordon, D. J. 2002. Effect of corn processing on degradable intake protein requirement of finishing cattle. Journal of Animal Science, **80**(1): 242-247. Doi: 10.2527/2002.801242x.

Dahlke, G. R. 2013. The feeding value of heat damaged distillers grains in cattle diets. Iowa State University Animal Industry Report 10(1). Doi: 10.31274/ans_air-180814-805

Das, L. K., Kundu, S. S., Kumar, D., Datt, C. 2015. Fractionation of carbohydrate and protein content of some forage feeds of ruminants for nutritive evaluation. Veterinary World, **8**(2), 197–202. Doi: 10.14202/vetworld.2015.197-202

Dunford, N. T. (2012). Advancements in Oil and Oilseed Processing. In Food and Industrial Bioproducts and Bioprocessing (pp. 115–143). Doi: 10.1002/9781119946083.ch4

Elsasser, T. H., Rosebrough, R. W., Rumsey, T. S., Moseley, W. M. 1996. Hormonal and nutritional modulation of hepatic arginase activity in growing cattle. Domestic Animal Endocrinology, **13**(3), 219–228. Doi: 10.1016/0739-7240(95)00068-2

Elwakeel, E. A., Amachawadi, R. G., Nour, A. M., Nasser, M. E. A., Nagaraja, T. G., Titgemeyer, E. C. 2013. In vitro degradation of lysine by ruminal fluid-based fermentations and by Fusobacterium necrophorum. Journal of Dairy Science, **96**(1), 495–505. Doi: 10.3168/jds.2012-5810

Espinosa, C. D., Stein, H. H. 2018. High-protein distillers dried grains with solubles produced using a novel front-end-back-end fractionation technology has greater nutritional value than conventional distillers dried grains with solubles when fed to growing pigs. Journal of Animal Science, **96**(5) : 1869-1876. Doi : 10.1093/jas/sky052

Faccenda, A., Zambom, M. A., Avila, A. S., Fernandes, T., Stum, M. M., Garcias, J., Tinini, R. C. R., Dias, A. L. G. 2018. Dried brewers' grain as a replacement for soybean meal on nutrient digestibility and rumen parameters of cattle. South African Journal of Animal Science. **48**(6). Doi: 10.4314/sajas.v48i6.12

Fontaine, J., Zimmer, U., Moughan, P. J., Rutherfurd, S. M. 2007. Effect of heat damage in an autoclave on the reactive lysine contents of soy products and corn distillers dried grains with solubles. use of the results to check on lysine damage in common qualities of these ingredients. Journal of Agricultural and Food Chemistry, **55**(26): 10737-10743. Doi: 10.1021/jf071747c

Getabalew, M., Negash, A. 2020. Nitrogen metabolism and recycling in ruminant animals: a review. Academic Journal of Nutrition, **9**(3): 29-38. Doi: 10.5829/idosi.ajn.2020.29.38

Getahun, D., Alemneh, T., Akeberegn, D., Getabalew, M., Zewdie, D. 2019. Urea metabolism and recycling in ruminants. Journal of Scientific and Technical Research. **20**(1): 14790-14796. Doi: 10.26717/BJSTR.2019.20.003401

Gleghorn, J. F., Elam, N. A., Galyean, M. L., Duff, G. C., Cole, N. A., Rivera, J. D. 2004. Effects of crude protein concentration and degradability on performance, carcass characteristics, and serum urea nitrogen concentrations of finishing steers. Journal of Animal Science, **82**: 2705–2717. Doi: 10.2527/2004.8292705x

Harmon, D. L., Swanson, K. C. 2020. Review: Nutritional regulation of intestinal starch and protein assimilation in ruminants. Animal (Cambridge, England), **14**(S1), s17–s28. Doi: 10.1017/S1751731119003136

Harris, C. 2008. Ethanol By-Products – a Good Feed Additive. [Online] Available : https ://www.thebeefsite.com/articles/1323/ethanol-byproducts-a-good-feed-additive/ [2023 Sept. 11].

Heuzé V., Tran G., Kaushik S., 2020. Soybean meal. Feedipedia [Online] Available: https://www.feedipedia.org/node/674 [2023 Sept. 1]

Cantalapiedra-Hijar, G., Ortigues-Marty, I., Sepchat, B., Titgemeyer, E., Bahloul, L. 2020. Methionine-balanced diets improve cattle performance in fattening young bulls fed high-forage diets through changes in nitrogen metabolism. British Journal of Nutrition. **124**(3): 273-285. Doi: 10.1017/S0007114520001154

Hoffman, L. A., Baker, A. 2011. Estimating the substitution of distillers' grains for corn and soybean meal in the U.S. feed complex. U.S. Department of Agriculture [Online] Available: https://www.ers.usda.gov/publications/pub-details/?pubid=36472 [2024 Feb. 20]

Huls, T. J., Bartosh, A. J., Daniel, J. A., Zelinsky, R. D., Held, J., Wertz-Lutz, A. E. 2006. Efficacy of Dried Distiller's Grains with Solubles as a Replacement for Soybean Meal. Small Ruminant Research, **201**: 106411. doi: 10.1016/j.smallrumres.2021.106411

Inhuber, V., Windisch, W., Bachler, B., Schuster, M., Spiekers, H., Ettle, T. 2021. Effects of supplementing a CP-reduced diet with rumen-protected methionine on Fleckvieh bull fattening. Animal. (Cambridge England). **15**(11): 100366. Doi: 10.1016/j.animal.2021.100366

Jacobs, J. L., Davis, D. B., Mullenix, M. K., Koebernick, J. C., Justice, S. M., Dillard, S. L., Muntifering, R. B., Stewart, R. L. 2022. Cottonseed characteristics related to beef

cattle consumption: protein degradability, digestibility, and gossypol content. Applied Animal Science, **38**(5), 409-416. Doi: 10.15232/aas.2022-02304

Johnson, L.; Smith, K., 2018. Fact sheet: Soybean processing. The Soybean Meal Information Center [Online] Available: https://www.soymeal.org/wp-content/uploads/2018/04/soybean_processing.pdf [2023 Oct. 21]

Kielb, E. P., Zachwieja, A., Mista, D., Zawadzki, W., Steciwko, A. Z. 2017. Use of corn dried distillers grains (DDGS) in feeding of ruminants. Frontiers in Bioenergy and Biofuels. doi: 10.5772/66357

Klopfenstein, T. J., Erickson, G. E., Bremer, V. R. 2008. BOARD-INVITED REVIEW: Use of distillers by-products in the beef cattle feeding industry. Journal of Animal Science, **86**(5):1223-1231. Doi: 10.2527/jas.2007-0550

Koenig, K. M., Newbold, C. J., McIntosh, F. M., Rode, L. M. 2000. Effects of protozoa on bacterial nitrogen recycling in the rumen. Journal of Animal Science, 78(9), 2431–2445. Doi: 10.2527/2000.7892431x

Kronaizl, A. 2023. Soybean group moves ahead with proposed $500 million project south of Mitchell [Online] Available: https://listen.sdpb.org/business-economics/2022-07-26/soybean-group-moves-ahead-with-proposed-500-million-project-south-of-mitchell [2023 Sept. 16]

Kutzli, I., Weiss, J., Gibis, M. 2021. Glycation of Plant Proteins Via Maillard Reaction: Reaction Chemistry, Technofunctional Properties, and Potential Food Application. Foods, **10**(2), 376-416. Doi : 10.3390/foods10020376

Lapierre, H., Pacheco, D., Berthiaume, R., Ouellet, D. R., Schwab, C. G., Dubreuil, P., Holtrop, G., Lobley, G. E. 2006. What is the True Supply of Amino Acids for a Dairy

Cow. Journal of Dairy Science, **89**, E1–E14. Doi: 10.3168/jds.S0022-0302(06)72359-1

Lawrence, T. E. 2022. Effect of Liver Abscessation on Carcass Outcomes. The Veterinary Clinics of North America. Food Animal Practice, 38(3), 361–365. doi: 10.1016/j.cvfa.2022.08.003

Li, X., Chen, S., Yu, Y., Wand, S., Xu, Z., Huang, H., Jin., M. 2019. Ethanol production from mixtures of distiller's dried grains with solubles (DDGS) and corn. Industrial Crops and Products, **129**, 59-66. Doi: 10.1016/j.indcrop.2018.11.075

Lotfy, S. N., Saad, R., El-Massrey, K. F., Fadel, H. H. M. 2021. Effects of pH on headspace volatiles and properties of Maillard reaction products derived from enzymatically hydrolyzed quinoa protein-xylose model system. Food Science & Technology, **145**, 111328-111337. Doi: 10.1016/j.lwt.2021.111328

Mæhre, H. K., Dalheim, L., Edvinsen, G. K., Elvevoll, E. O., Jensen, I. J. 2018. Protein Determination-Method Matters. Foods, **7**(1), 5. Doi: 10.3390/foods7010005

Mjoun, K., Kalscheur, K. F., Hippen, A. R., & Schingoethe, D. J. 2010. Ruminal degradability and intestinal digestibility of protein and amino acids in soybean and corn distillers grains products. Journal of Dairy Science, **93**(9), 4144–4154. Doi: 10.3168/jds.2009-2883

Nagaraja, T. G., Chengappa, M. M. 1998. Liver abcesses in feedlot cattle: a review. Journal of Animal Science, **76**(1): 287-298. Doi: 10.2527/1998.761287x

Nagaraja, T. G., Lechtenberg, K. F. 2007. Liver Abscesses in Feedlot Cattle. The Veterinary Clinics of North America. Food Animal Practice, **23**(2), 351–369. Doi: 10.1016/j.cvfa.2007.05.002

NASEM (National Academies of Sciences, Engineering, and Medicine). 1996. Nutrient Requirements of Beef Cattle. Revised 6th Ed.. National Academy Press, Washington, DC. doi: 10.17226/19014

NASEM (National Academies of Sciences, Engineering, and Medicine). 2000. Nutrient Requirements of Beef Cattle. Revised 7th Ed.. National Academy Press, Washington, DC. doi: 10.17226/9791

NASEM (National Academies of Sciences, Engineering, and Medicine). 2016. Nutrient Requirements of Beef Cattle. Revised 8th Ed.. National Academy Press, Washington, DC. doi: 10.17226/19014

Neeley, T. 2021. KS Bean Crush Plant To Be Built [Online] Available: https://www.dtnpf.com/agriculture/web/ag/news/business-inputs/article/2021/10/13/soybean-crushing-plant-will-give [2023 Sept. 16]

Newkirk, R. 2011. Wheat DDGS Feed Guide: Wheat dried distiller grains with solubles. Feed Opportunities from the Biofuels Industries (FOBI). Canadian International Grains Institute (Cigi) 1

Oba, P. M., Hwisa, N., Huang, X., Cadwallader, K. R., Swanson, K. S. 2022. Nutrient and Maillard reaction product concentrations of commercially available pet foods and treats. Journal of Animal Science, **100**(11). Doi: 10.1093/jas/skac305

Olukoski, O. A., Adebiyi, A. O. 2013. Chemical 36omposition and prediction of amino acid content of maize- and wheat-Distillers' Dried Grains with Soluble. Animal Feed Science and Technology, **185**(3-4): 182-198. Doi: 10.1016/j.anifeedsci.2013.08.003

Owens, F. N., Zinn, R. 1988. Protein metabolism of ruminant animals. In: D.C. Church, editor, The Ruminant Animal: Digestive Physiology and Nutrition. Prentice Hall, Englewood Cliffs, NJ. P. 227 – 249.

Owens, F. N., Qi, S., Sapienza, D. A. 2014. INVITED REVIEW: Applied protein nutrition of ruminants—Current status and future directions. Professional Animal Scientist, **30**(2), 150–179. Doi: 10.15232/S1080-7446(15)30102-9

Pérez-Barbería, F. J. 2020. The ruminant : life history and digestive physiology of a symbiotic animal. Sustainable and Environmentally Friendly Dairy Farms, 19-45. Doi: 10.1007/978-3-030-46060-0_2

Putri, E. M., Zain, M., Warly, L., Hermon, H. 2021. Effects of rumen-degradable-to-undegradable protein ratio in ruminant diet on in vitro digestibility, rumen fermentation, and microbial protein synthesis. Veterinary World, **14**(3): 640-648. Doi: 10.14202/VETWORLD.2021.640-648

Reidy, J. 2022. Construction begins on soybean processing plant [Online] Available: https://www.foodbusinessnews.net/articles/22087-construction-begins-on-soybean-processing-plant [2023 Sept. 16]

Reynolds, C., Kristensen, N. 2008. Nitrogen recycling through the gut and the nitrogen economy of ruminants: An asynchronous symbiosis. Journal of Animal Science, 86(14), E293–E305. Doi: 10.2527/jas.2007-0475

Ribeiro, G. O., Hunerberg, M., Gibb, D., McAllister, T. A. 2016. Impact of low- and medium-oil corn dried distillers' grains plus solubles on growth performance of feedlot cattle. Canadian Journal of Animal Science, **97**(3):530-535. Doi: 10.1139/cjas-2016-0157

Russell, J. B., O'Connor, J. D., Fox, D. J., Van Soest, P. J., Sniffen, C. J. 1992. A net carbohydrate and protein system for evaluating cattle diets: I. Ruminal fermentation, Journal of Animal Science. **70**(11); 3551–3561. Doi: 10.2527/1992.70113551x

Russell, J. B. 2005. Enrichment of fusobacteria from the rumen that can utilize lysine as an energy source for growth. Anaerobe. **11**(3):177–184. Doi: 10.1016/j.anaerobe.2005.01.001

Salami, S. A., Devant, M., Apajalahti, J., Holder, V., Salomaa, S., Keegan, J. D., Moran, C. A. 2021. Slow-Release Urea as a Sustainable Alternative to Soybean Meal in Ruminant Nutrition. Sustainability, **13**(5): 2464. Doi:10.3390/su13052464

Salim, H., Wood, K. M., Cant, J. P., Swanson, K. C. 2015. Influence of feeding increasing levels of dry or modified wet corn distillers' grains plus solubles in whole corn grain-based finishing diets on hepatic and renal mass, and glutathione peroxidase and urea cycle enzyme activities in finishing cattle. Canadian Journal of Animal Science, **95**(3), 407–415. Doi: 10.4141/cjas-2014-134

Samuelson, K. L., Hubbert, M. E., Galyean, M. L., Löest, C. A. 2016. Nutritional recommendations of feedlot consulting nutritionists: The 2015 New Mexico State and Texas Tech University survey. Journal of Animal Science, **94**(6), 2648–2663. Doi: 10.2527/jas.2016-0282

Saunders, J. A., Rosentrater, K. A. 2009. Properties of solvent extracted low-oil corn distillers dried grains with solubles. Biomass and Energy, **33**(10): 1486-1490. Doi: 10.1016/j.biombioe.2009.07.004

Schumacher, E. A., Erickson, G. E., Wilson, H. C., Norman, M. M., MacDonald, J. C., Watson, A. K., Klopfenstein, T. J. 2020. Comparison of Rumen Undegradable

Protein Content of Conventional and Organic Feeds. Journal of Animal Science. **97**(2): 227. Doi: 10.1093/jas/skz122.399

Schwab, C. G., Tylutki, T. P., Ordway, R. S., Sheaffer, C., Stern, M. D. 2003. Characterization of Proteins in Feeds. Journal of Dairy Science, **86**(13), E88–E103. Doi: 10.3168/jds.S0022-0302(03)74042-9

Schwarz, C., Mathieu, J., Gomez, J. L., Miller, M. R., Tikhonova, M., Nagaraja, T. G., Alvarez, P. J. J. 2023. Unexpected finding of Fusobacterium varium as the dominant Fusobacterium species in cattle rumen: potential implications for liver abscess etiology and interventions. Journal of Animal Science, **101**: 1-12. Doi: 10.1093/jas/skad130

Shad, Z. M., Venkitasamy, C., Wen, Z. 2021. Corn distillers fried grains with solubles: production, properties, and potential uses. Cereal Chemistry, **98**(5): 999-1019. Doi: 10.1002/cche.10445

Shen, J., Li, Z., Yu, Z., Zhu, W. 2020. Effects of dietary replacement of soybean meal with dried distillers grains with solubles on the microbiota occupying different ecological niches in the rumen of growing Hu lambs. Journal of Animal Science and Biotechnology. **11**(1):93. Doi: 10.1186/s40104-020-00499-2

Sinclair, L.A., Garnsworth, P. C., Newbold, J. R., Buttery, P. J. 1993. Effect of synchronizing the rate of dietary energy and nitrogen release on rumen fermentation and microbial protein synthesis in sheep. Journal of Agricultural Science. **120**(2): 251-263. Doi:10.1017/S002185960007430X

Sorensen, R. J., Stewart, S. S., Jones, C. K., Crane, A. R., Lattimer, J. M. 2021. Efficacy of corn dried distillers grains with solubles as a replacement for soybean meal in Boer-

cross goat finishing diets. Small Ruminant Research. **201**: 106411. Doi: 10.1016/j.smallrumres.2021.106411

Souza, V. C., White, R. R. 2021. Variation in urea kinetics associated with ruminant species, dietary characteristics, and ruminal fermentation: A meta-analysis. Journal of Dairy Science, **104**(3): 2935–2955. Doi: 10.3168/jds.2020-19447

Stein, H. H., Shurson, G. C. 2009. Board invited review: The use and application of distillers dried grains with solubles (DDGS) in swine diets. Journal of Animal Science, **87**:1292-1303. Doi: 10.2527/jas.2008-1290

Stewart, L. 2017. Using Distillers Grains in Beef Cattle Diets [Online] Available: https://extension.uga.edu/publications/detail.html?number=B1482 [2023 Sept. 13]

Suriyapha, C., Suntara, C., Wanapat, M., Cherdthong, A. 2022. Effects of Substituting Agro-Industrial By-Products for Soybean Meal on Beef Cattle Feed Utilization and Rumen Fermentation. Scientific Reports. **12**(1): 21630-21630. Doi: 10.1038/s41598-022-26191-1

Swanson, K. C. 2019. Small intestinal anatomy, physiology, and digestion in ruminants. Reference Module in Food Science. Doi: 10.1016/B978-0-08-100596-5.22638-3

Tamang, S., Aryal, S. 2023. Alchoho, Fermentation (Ethanol): Process, Steps, Uses [Online] Available: https://microbenotes.com/alcohol-fermentation-ethanol/ [2024 Mar. 8]

Tedeschi, L. O., Fox, D. G., Russell, J. B. 2000. Accounting for the effects of a ruminal nitrogen deficiency within the structure of the Cornell Net Carbohydrate and Protein System, Journal of Animal Science. **78**(6) ; 1648–1658. Doi : 10.2527/2000.7861648x

Tedeschi, L. O., Fox, D. G., Fonseca, M. A., Cavalcanti, L. F. L. 2015. Models of protein and amino acid requirements for cattle. Revista Brasileira de Zootecnia, **44**(3), 109–132. Doi: 10.1590/S1806-92902015000300005

Teodorowicz, M., Heniks, W. H., Wichers, H. J., Savelkoul, H. F. J., LS Voeding. 2018. Immunomodulation by Processed Animal Feed: The Role of Maillard Reaction Products and Advanced Glycation End-Products (AGEs). Frontiers in Immunology, **9**: 2088–2088. Doi: 10.3389/fimmu.2018.02088

Vaiknoras, K. 2023. U.S. soybean production expands since 2002 as farmers adopt new practices, technologies [Online] Available : https://www.ers.usda.gov/amber-waves/2023/july/u-s-soybean-production-expands-since-2002-as-farmers-adopt-new-practices-technologies/#:~:text=U.S.%20planted%20soybean%20acreage%20increased%2018%20percent%20from,the%20mid-1990s%2C%20saw%20rapid%20adoption%20among%20soybean%20farmers [2023 Sept. 14]

Wagner, J. J., Engle, T. E., Bryant, T. C. 2010. Effect of rumen degradable and rumen undegradable intake protein on feedlot performance and carcass merit in heavy yearling steers. Journal of Animal Science, **88**(3): 1073–1081. Doi: 10.2527/jas.2009-2111

Wang, Y., Chung, D. S., Spillman, C. K. 1995. Physical Properties of Soybean Meal. Cereal Chemistry. **72**(6): 523-526.

Watson, A. K., Klopfenstein, T. J., Erickson, G. E., MacDonald, J. C., Wilkerson, V. A. 2017. Impact of microbial efficiency to predict MP supply when estimating protein

requirements of growing beef cattle from performance. Journal of Animal Science, **95**(7), 3184–3191. Doi: 10.2527/jas.2016.1124

Wilde, M. 2021. Farmers Have Crush on New Soybean Plant [Online] Available: https://www.dtnpf.com/agriculture/web/ag/news/article/2021/05/12/construction-underway-270-million [2023 Sept. 16]

Xue F., Zhou Z., Ren L., and Meng Q.. 2011. Influence of rumen-protected lysine supplementation on growth performance and plasma amino acid concentrations in growing cattle offered the maize stalk silage/maize grain-based diet. Animal Feed Science Technology. **169**(1):61–67. Doi: 10.1016/j.anifeedsci.2011.05.011

Yu, Z. P., M. Xu, J. H. Yao, K. Liu, F. Li, Y. Liu, F. Wang, F. F. Sun, N. N. Liu. 2013. Regulation of pancreatic exocrine secretion in goats: Differential effects of short- and long-term duodenal phenylalanine treatment. Journal of Animal Physiology and Animal Nutrition, **97**(3), 431–438. Doi: 10.1111/j.1439-0396.2012.01276.x

Zhang, Q., Ames, J. M., Smith, R. D., Baynes, J. W., Metz, T. O. 2009. A Perspective on the Maillard Reaction and the Analysis of Protein Glycation by Mass Spectrometry: Probing the Pathogenesis of Chronic Disease. Journal of Proteome Research, **8**(2), 754–769. Doi: 10.1021/pr800858h

TABLES

Table 1.1. Empty body protein (EBP) amino acid requirement and amino acid (AA) content of soybean meal and distillers grains (g/100g of CP).

		Soybean Meal[b]		Distillers, Corn[b]	
AA	EBP AA Req[a]	Solv. Extracted	Expelled	Dried	Modified
Arginine	3.3	7.10	7.06	4.74	4.60
Histidine	2.5	2.79	2.80	3.00	2.92
Isoleucine	2.8	4.80	5.02	4.04	3.87
Leucine	6.7	7.97	8.14	11.74	10.80
Lysine	6.4	6.47	6.05	3.48	3.43
Methionine	2.0	1.43	1.42	2.04	1.90
Phenylalanine	3.5	5.02	5.09	4.52	4.20
Threonine	3.9	3.82	3.71	3.78	3.58
Valine	4.0	5.00	4.80	5.30	5.15

[a] NASEM, 2016

[b] Mjourn et al., 2010

Table 1.2. The nutrient content of feedstuffs as provided by the Nutrient Requirements of Beef Cattle, 2016[a].

	Soybean Meal[c]		Distillers Grain Solubles[c]	
Item[b]	Solvent Extracted, without hulls	Expeller Pressed, without hulls	Corn, Dried	Corn, Modified
Ash	7.36 ± 0.69	-	5.32 ± 0.88	6.65 ± 0.72
TDN	79.5 ± 1.33	77.0	89.0 ± 4.48	93.0 ± 5.71
Starch	2.02 ± 0.80	-	5.88 ± 2.43	3.36 ± 1.07
Fat	1.88 ± 1.12	8.17 ± 1.85	-	-
NDF	11.33 ± 2.41	12.60	33.66 ± 3.51	28.73 ± 3.67
ADF	7.48 ± 1.46	8.80 ± 0.42	16.17 ± 3.15	14.81 ± 3.06
CP	52.85 ± 1.32	46.54 ± 1.95	30.79 ± 2.67	29.08 ± 2.45
RUP, %CP	29.45 ± 6.67	-	67.93 ± 6.27	-
RDP, % CP	70.42 ± 6.94	-	32.00 ± 6.26	-

[a] All values are on a DM basis

[b] TDN = total digestible nutrients; NDF = neutral detergent fibre; ADF = acid detergent fibre; CP = crude protein; RUP = rumen undegradable protein; RDP = rumen degradable protein

[c] NASEM, 2016

CHAPTER II: SUBSTITUTION OF MODIFIED DISTILLERS GRAINS WITH SOYBEAN MEAL WITH OR WITHOUT HULLS HAD NEGLIGIBLE EFFECT ON GROWTH PERFORMANCE, EFFICIENCY, AND CARCASS TRAITS IN YEARLING STEERS

ABSTRACT

Changes to the fuel landscape in the United States have resulted in changing of long-held supplemental protein price relationships. The objectives of this study were to evaluate animal performance, carcass traits, and dietary net energy utilization in finishing beef steers when soybean meal (SBM) with or without soybean hulls (SBH) replaced modified distillers plus solubles (MDGS). Angus-based steers [n = 240; initial shrunk body weight (BW) = 435 ± 23.2 kg] were used in a 118-d experiment. Steers were blocked by location within the feedlot and randomly assigned to three treatments: MDGS fed at 15% diet DM (MDGS) replaced by either soybean meal and corn (9 and 6% of DM, respectively; SBM), or soybean meal and soyhull pellets (9 and 6% of DM, respectively; SBM-SBH). Steers were individually weighed and allotted to one of 24 pens (n = 10 steers per pen; 8 pens per treatment) at the Southeast Research Farm located near Beresford, SD. Dietary concentrations of crude protein and neutral detergent fiber based on tabular values and weekly batching records were 12.3 and 17.6%, 12.8 and 14.5%, and 12.8 and 17.8% for MDGS, SBM, and SBM-SBH, respectively. Data were analysed as a randomized complete block design using the GLIMMIX procedure of SAS 9.4. The model included block as a random effect and the fixed effect of treatment; pen was the experimental unit. Pen conditions were wet and muddy during the final weeks of this experiment;

consequently, final BW was calculated by dividing hot carcass weight (HCW) by a common dressing percentage of 62.5. No differences amongst treatments ($P \geq 0.11$) were observed for carcass-adjusted final BW, dry matter intake (DMI), average daily gain (ADG), or feed efficiency. Dietary treatment had no effect ($P \geq 0.11$) on HCW, dressing percentage, ribeye area, rib fat, marbling score, USDA Yield Grade, percent empty body fat (EBF), or final body weight adjusted to 28% EBF. Distribution of USDA Quality or Yield grades were unaffected by treatment ($P \geq 0.39$). Dietary treatment did not affect liver abscess incidence or severity ($P = 0.11$). Net energy values calculated from animal performance agreed closely with tabular estimates with observed to expected ratios for net energy equalling one. In this experiment, feeding supplemental protein sources with enhanced diet conditioning attributes and greater concentrations of ruminally undegradable protein provided no advantage to cattle performance. These results indicate that protein source decisions between MDGS and SBM can be based upon price per unit of delivered crude protein.

INTRODUCTION

Traditionally, corn-milling co-products are used as a standard feed ingredient in American feedlots, whereas oilseed by-products are rarely used. Consequently, current research on the efficiency of use of soybean by-products such as soybean meal in feedlot diets is limited. The effects of soybean meal in comparison to distillers co-products in finishing cattle diets have been studied previously (Firkins et al., 1984); however, since that time advancements in growth enhancement technologies and cattle genetics have been made, further reinforcing the need for updated research.

The two major by-products of soybean processing, soybean hulls and soybean meal offer high quality feed to livestock. Soybean hulls are easily pelleted and offer a highly fermentable fibre source to a total mixed ration (Huls et al., 2006), while soybean meal contains a high concentration of crude protein and rumen degradable protein (Suriyapha et al., 2022). When compared to distillers co-products, soybean meal has the advantage in consistency of nutrient composition as a result of fractionation technology of ethanol plants continuing to evolve and change (Hoffman and Baker, 2011).

Soybean is among the worlds most important crops, both for food and feed quality products (Arnall et al., 2020). Soybean is one of the largest sources of animal feed and vegetable oil worldwide (Pagano and Miransari, 2016). The increasing demand for low carbon fuel has increased the demand for renewable diesel production, and thus soybean oil (USDA, 2024). Recent projections for 2024/25 report 8% greater soybean production in the United States (USDA, 2024). This increase in soybean production is likely to result in greater supplies of soybean meal and soyhulls and potentially favorable prices for these by-products for feedlot producers. Therefore, the objectives of this study were to

evaluate animal performance, carcass traits, and dietary net energy utilization in finishing beef steers when soybean meal (SBM) with or without soybean hulls (SBH) replaced modified distillers plus solubles (MDGS). We hypothesized that replacing modified distillers grains plus solubles with soybean processing co-products would improve cattle performance.

MATERIALS AND METHODS

Institutional Animal Care and Use Approval

All experimental protocols were approved by the South Dakota State University Institutional Animal Care and Use Committee (Approval Number: 2209-052E).

Animals, Initial Processing, and Study Initiation

Single sourced predominantly Angus steers (n = 240) were utilized in a 118-d feedlot finishing experiment at the South Dakota State University Southeast Research Farm (SERF) located near Beresford, SD. Steers were procured from a South Dakota auction facility one week prior to study initiation. Upon arrival, steers were placed in open lot dirt pens (n = 10 steers/pen) and provided ad libitum access to long-stem grass hay and water.

Approximately 48 h after arrival (d -4) steers were administered an individual ID tag, vaccinated against viral respiratory (Bovi-Sheild Gold 5, Zoetis; Parsipanny, NJ) and clostridia pathogens (Ultrabac 7/Somubac, Zoetis) and administered pour-on moxidectin (Cydectin, Bayer Healthcare LLC, Shawnee Mission, KS) according to label instructions. An individual BW was obtained at this time which was used for allotment purposes. On d

0 steers were weighed again, blocked by location within the feedyard (n = 8), and allotted to study pens (n = 24). The combined d -4 and d 0 BW were used as the initial BW (initial shrunk [4%] BW = 435 ± 23.6 kg). Steers were administered a steroidal implant on d 21 (200 mg trenbolone acetate and 28 mg estradiol benzoate; Synovex-PLUS, Zoetis, Parsippany, NJ). Implant sites were inspected on d 49 for abnormalities.

Experimental Design and Treatments

This study used 24 pens (n = 8 pens/treatment; n = 10 steers/pen) and each pen was assigned to 1 of 3 dietary treatments: 1) a diet containing MDGS at 15% diet DM [**MDGS**], 2) a diet replacing MDGS with SBM and corn [**SBM**], 3) a diet replacing MDGS with SBM and SBH [**SBM-SBH**]. All diets were formulated to be isonitrogenous and MDGS and SBM-SBH were formulated to contain equivalent concentrations of NDF.

Diets and Intake Management

Fresh feed was manufactured once daily at 0800h in a commercial mixer wagon (5.2 m^3; scale readability ± 0.91 kg) and bunks were managed according to a slick bunk management system to avoid feed carry-over. Bunks were visually appraised once daily at 0730 h to determine daily feed allocation. Animals which were removed from the study because of mortality or chronic disease were assumed to have consumed feed equal to the pen average DMI up to the point of removal from the study. Two steers (one from MDGS and one from SBM) were removed from the study for reasons unrelated to dietary treatment, therefore all data reported are on a removals excluded basis.

Steers were transitioned from a 70% concentrate to a 90% concentrate diet over a 14-d period. Final diet composition is presented in Table 2.1. Because of feed availability, roughage sources were ryelage (d 1 to 44), corn silage (d 45 to 105), and sorghum silage (d 106 to 118). Actual diet formulation and nutrient composition was determined based on weekly feed analyses and corresponding feed batching records. Diets were fortified to provide vitamins and minerals to meet or exceed nutrient requirements and provided monensin sodium at 30g/ton of diet DM (NASEM, 2016). Ingredient samples were dried in a forced air oven at 60°C until no weight change. Weekly ingredient samples were stored in a freezer at -20 ºC until nutrient analyses were completed. After DM determination (method no. 935.29; AOAC, 2012), weekly samples from each ingredient were analyzed for N (method no. 968.06; AOAC, 2016; Rapid Max N Exceed; Elementar; Mt. Laurel, NJ), and ash (method no. 942.05; AOAC, 2012). When necessary, orts were collected, weighed, and dried in a forced air oven at 60°C for 24 h to determine DM content. The dry matter intake (DMI) of the pen was adjusted to reflect the total DM delivered to each pen after subtracting dry orts for each period.

Growth Performance Collection and Carcass Trait Determination

Steers were individually weighed on d -4, 0, 21, 49, and 118 (study termination). Body weights were measured prior to morning feeding and a 4% pencil shrink was applied to all BW measures to account for gastrointestinal tract fill. Cumulative growth performance was calculated on a live and carcass-adjusted basis. At time of harvest, weather related conditions had produced substantial tag on hide, thus all values used are on a carcass-adjusted basis. Carcass adjusted final BW was calculated from hot carcass

weight (HCW) divided by 0.625. Average daily gain (ADG) was calculated as the difference between final BW (FBW) and initial shrunk BW, divided by days on feed (118 d). Efficiency of weight gain (G:F) was calculated by dividing ADG by daily DMI. Dry matter intake was tabulated at weekly intervals and summarized by interim period.

Steers were harvested after 118 d on feed when appraised to have 1.5 cm of fat at the 12th rib (RF). Steers were shipped in the afternoon following final BW determination and harvested the following day at a commercial abattoir. Steers were comingled at the time of shipping until time of harvest at approximately 0700 h the day after shipping. At time of harvest, hot carcass weight (HCW) and liver health outcomes were collected, and video image data was obtained from the abattoir for rib eye area (REA), rib fat (RF), marbling scores, and USDA Quality and Yield grades. Liver scores were determined by a trained technician and classified according to the Elanco Liver Scoring System: normal (no abscesses), A- (1 or 2 small abscesses or abscess scars), A (2 to 4 well-organized abscesses less than 2.54 cm in diameter), or A+ (1 or more large active abscesses greater than 2.54 cm in diameter with inflammation of surrounding tissue). Dressing percentage (DP) was calculated as HCW/(final BW × 0.96). A common kidney, pelvic, and heart (KPH) fat percentage of 2.5% was applied to the USDA regression equation (USDA, 1997). Estimated empty body fat (EBF) percentage and adjusted final body weight (AFBW) were calculated from observed carcass traits (Guiroy et al., 2002), as well as estimated proportion of closely trimmed boneless retail cuts from carcass round, loin rib, and chuck [Retail Yield (RY); Murphey et al., 1960]. Carcass data was unavailable for two steers from MDGS treatment.

Carcass-adjusted growth performance was used to calculate performance-based dietary NE to determine the efficiency of dietary NE utilization. Performance-adjusted NE was calculated from daily energy gain (EG; Mcal/d) using the following equation (NASEM, 2016):

$EG = ADG^{1.097} \times 0.0557BW^{0.75}$,

where BW is the mean equivalent metabolic shrunk BW (kg) calculated as shrunk BW × (478/AFBW), where AFBW is the adjusted final body weight.

Maintenance energy (EM; Mcal/d) was calculated using the following model:

$EM = 0.077 \times BW^{0.75}$.

Dry matter intake (DMI) is related to energy requirements and dietary NEm (Mcal/kg) according to the following equation: DMI = EG/(0.877NEm – 0.41), and can be resolved for estimation of dietary NEm by means of the quadratic formula (Zinn and Shen, 1998):

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2c},$$

where x = NEm, Mcal/kg, a = -0.41EM, b = 0.877EM + 0.41DMI + EG, c = -0.877DMI.

Dietary net energy for gain (NEg; Mcal/d) was determined from NEm using the following equation (Zinn et al., 2008): NEg = 0.877NEm – 0.41.

Retained energy (RE) was calculated based on the following (NASEM, 2016):

$RE\ (Mcal/d) = 0.0635 \times EBW^{0.75} \times EBG^{1.097}$.

Retained protein (RP, g/d) was calculated using the following model (NASEM, 2016):

$RP = SWG \times \{268 - [29.4 \times (RE/SWG)]\}$

Statistical Analysis

Growth performance, carcass traits, and efficiency of dietary energy were analysed as a completely randomized block design (RCBD) using the GLIMMIX procedure of SAS 9.4 (SAS Inst. Inc., Cary, NC) with pen as the experimental unit. The model included block as a random effect and the fixed effect of treatment. Orthogonal contrasts were used to determine the effects of protein source (MDGS versus SBM and SBM-SBH) or starch compared to NDF (SBM versus MDGS and SBM-SBH). Distributions of USDA Quality grade and Yield grade, and liver abscess prevalence and severity were analysed as multinomial distributions using the GLIMMIX procedure of SAS 9.4. Individual animal was the experimental unit for categorical outcome data with the same random and fixed effects used in the model as previously described. Dry matter intake was analysed using the GLIMMIX procedure of SAS 9.4 using repeated measures and least squares means were generated using the LSMEANS statement of SAS 9.4. An α of 0.05 was used to determine significance and an α of 0.06 to 0.10 was considered a tendency.

RESULTS

Growth Performance

On the first 21 d (Table 2.3), feeding SBM increased growth compared to MDGS. Body weight on day 21 was greater (P = 0.01) for SBM and SBM-SBH compared to MDGS (491, 489, and 471 kg, respectively). This was reflected by 41 and 38 % greater ADG (P = 0.01) observed in the SBM and SBM-SBH treatments on d 21. Further,

soybean meal increased DMI ($P = 0.01$) and G:F ($P = 0.01$) compared to MDGS. No difference in DMI ($P = 0.26$) was observed from d 22 to 49. On d 49, G:F was decreased in the SBM treatments ($P = 0.01$; 0.214 [MDGS] vs. 0.187 [SBM], 0.185 [SBM-SBH]) and MDGS had greater ADG compared to the SBM treatments ($P = 0.03$). Cumulatively, DMI was not affected by protein source ($P = 0.68$). Live-basis FBW, ADG, and G:F were unaffected by dietary treatment ($P \geq 0.15$). However, a tendency was observed for decreased G:F in the soybean meal treatments compared to MDGS ($P = 0.07$) and a tendency for a starch effect resulting in greater ADG for SBM compared to SBM-SBH ($P = 0.09$). On a carcass-adjusted basis, we observed no differences amongst treatments ($P \geq 0.11$) for FBW, ADG, or G:F. Soybean meal did tend to reduce carcass-adjusted FBW when compared to MDGS ($P = 0.09$). Net energy for maintenance and NEg did not differ ($P = 0.19$) between treatments. The average NEm was 2.03 Mcal/kg, and the average NEg was 1.37 Mcal/kg. Protein retained for the MDGS, SBM, and SBM-SBH treatments were 206.3, 206.9, and 202.1 g/d, respectively.

Carcass Traits

Dietary treatment did not have an effect ($P \geq 0.51$) on RF, marbling score, RY, or EBF (Table 2.4). Similarly, dietary treatment did not affect ($P \geq 0.11$) HCW, DP, REA, or AFBW. Soybean meal tended to decrease HCW ($P = 0.09$) and REA ($P = 0.07$) and decreased DP ($P = 0.05$; 61.96, 61.14 and 61.23% for MDGS, SBM, and SBM-SBH, respectively. Distribution of USDA Yield Grades ($P = 0.39$) nor USDA Quality Grades ($P = 0.70$) were affected by dietary treatment. Liver abscess prevalence and severity were not affected by dietary treatment ($P = 0.11$).

DISCUSSION

Growth Performance

Data reported herein show no differences in animal performance, carcass traits, and dietary net energy utilization in finishing beef steers when SBM is fed with or without soybean hulls in replacement of MDGS. These data are interpreted to imply that replacement of MDGS with SBM and SBH provided no advantage or disadvantage to cattle performance.

In the first 21 d of the experiment, substituting SBM increased live performance compared to MDGS with greater interim body weight, ADG, DMI, and G:F. Although the cause of this difference is not clear, we hypothesize that SBM provided steers with an amino acid (AA) profile that more closely matches increased requirements during this period. However, these responses were not consistent into the d 22 to 49 interim period. Steers in the MDGS treatment had improved ADG and G:F with similar DMI during the d 22 to 49 period, although with lesser BW at d 49. Cumulatively, no overall treatment differences were observed in live or carcass-adjusted growth performance. When comparing treatments based upon protein source, soybean meal tended to decrease G:F on a live-basis and tended to decrease FBW on a carcass adjusted basis. Likewise, when analysing the effect of increased starch inclusion in the SBM treatment a tendency for improved ADG was observed.

Results of the present study are not consistent with those reported by Mateo et al., (2004). On the first 28 d of their trial comparing SBM to wet or dry distillers grains fed at either 20 or 40% of diet DM to finishing beef steers, they reported an advantage of

distillers grains over SBM treatments in ADG and G:F. However, on day 56, SBM had greater ADG and G:F than DDGS at similar crude protein content. Cumulatively, no differences were observed. It should be noted that the distillers grains fed in that experiment had greater fat concentration compared to the MDGS fed in the current experiment.

Although not statistically significant, we observed numerical decreases in FBW, DMI and G:F in SBH fed cattle. In studies with greater dietary inclusion of soybean hulls in replacement of a portion of corn, decreases in cattle performance are often observed (Anderson et al., 1988; Ludden et al., 1995; Bittner et al., 2016). Past studies evaluating the effect of soybean hull inclusion in finishing diets reported linear decreases in FBW, ADG, and G:F (Ludden et al., 1995; Bittner et al., 2016). However, inconsistencies in DMI have been reported, resulting in either a linear decrease (Bittner et al., 2016) or linear increase (Ludden et al., 1995) in DMI with increasing inclusion of soybean hulls. Similarly, Anderson et al., (1988) reported an increase in DMI with dietary inclusion of soybean hulls at the expense of G:F.

Metabolizable protein and amino acid requirements of finishing cattle are greater in the initial period of a finishing diet (Klemesrud et al., 2000) due to lean tissue accretion (Fox and Black, 1984). The amino acid content of SBM may be the cause of increased growth performance of steers fed SBM in the first 21 d of the current experiment. Solvent extracted soybean meal has greater lysine content than that of distillers coproducts with approximately 6.16% and 2.81% of CP, respectively (NASEM, 2021). Klemesrud et al. (2000) supplemented rumen protected lysine to finishing calves fed a corn and wet corn gluten feed-based diet. The levels of rumen protected lysine

supplemented were 0, 1, 2, 3, 4, 6, 8, 10 and 12 g/d. Steers supplemented with 3 and 4 g/d lysine had 0.28 kg increased ADG and greater G:F compared to control in the first 56 d. Cumulatively, no differences were observed in live growth performance or carcass characteristics. However, differing results were observed by Heiderscheit et al., (2020) in a study comparing three finishing steer diets differing in lysine content and protein source. Treatments consisted of a lysine deficient diet (CON), a soybean meal diet sufficient in lysine (POS), and a distillers grains treatment including additional rumen protected lysine (RPL). Cattle fed diets deficient in lysine had greater FBW and overall ADG than POS and RPL treatments. No differences were observed between POS and RPL fed cattle in interim or cumulative growth performance measures or carcass characteristics. Furthermore, Teixeira et al. (2019) analysed lysine supplementation in a DDGS based diet utilizing 120 finishing steers. No live performance differences were observed between treatments. Lysine supplementation did result in increased REA but decreased fat thickness without affecting marbling score.

In this study, the MDGS treatment had less dietary DM concentration compared to SBM and SMB-SBH (65.4, 72.2, and 72.2% DM, respectively) which should have improved diet conditioning attributes. Studies have shown greater moisture content in cattle rations is beneficial in decreasing feed sorting behaviour (Leonardi et al., 2005; Miller-Cushon and DeVaries, 2009). Increased feed sorting has been linked to an increase in sub-acute ruminal acidosis in cattle potentially leading to negative implications on health and production (Miller-Cushon and DeVries, 2017). Neither ruminal pH nor cattle feeding behavior were measured in this experiment; however, increased dietary moisture content for MDGS in the current experiment did not result in cumulative improvements

in steer performance. It should be noted, feed deliveries in this study were managed according to a slick bunk management approach. Thus, resulting in limited indications of feed sorting behaviour.

Carcass Traits

Carcass characteristics in the current experiment were largely unaffected by dietary treatment, with the exception of decreased dressing percentage for SBM treatment and tendencies for reduced HCW and smaller REA. This agreed with data from a two-year study comparing SBM to WDGS or DDGS where no differences in carcass characteristics were observed (Mateo et al., 2004). Pittaluga et al., (2021) compared protein source of distillers grains and soybean meal with high and low levels of non-roughage NDF content (NRFC) in a 2 × 2 factorial using finishing steers. Non-roughage NDF was included in the diet as soybean hulls. No interaction between protein source (PS) and level of NRFC was observed. Protein source did not affect dressing percent, HCW, REA, RF, or marbling score. However, cattle fed high levels of NRFC had decreased RF in that experiment.

Studies conducted in small ruminants also have reported few differences in carcass traits when comparing soybean meal and distillers protein sources. Sorenson et al. (2021) compared the effects of DDGS and SBM in a finishing Boer goat trail. Feeding DDGS resulted in improved ADG and feed efficiency with no differences in carcass traits between treatments. However, Huls et al. (2006) compared SBM and DDGS fed to finishing lambs and reported no differences in growth performance or carcass outcomes between protein sources. In another growing and finishing lamb trial, Shen et al. (2020),

analysed the differences in digestibility and rumen ecological niches in animals fed DDGS and SBM. No differences were observed in bacterial communities withing the rumen ecology between treatments. However, it was reported that protozoa populations were reduced in the DDGS treatment. Huuskonen et al., (2014) completed a meta-analysis of the effects of protein source in growing cattle and concluded that protein source has minimal effect on carcass characteristics provided that adequate rumen-degradable protein was fed to allow sufficient rumen fermentation. In finishing diets fed to heavy yearling steers, providing greater than 5.1% RUP did not affect carcass measurements (Wagner et a., 2010). Results from the current study further support this conclusion.

In the present study, we observed no difference in distribution of USDA Quality or Yield grades among treatments. These results are not surprising considering the lack of treatment differences for RF, REA, or marbling scores. The lack of differences for USDA grading distributions in the current experiment are similar to observations of Trenkle (1998) when urea, SBM, and distillers co-products were fed to finishing beef cattle.

No statistical differences were observed for liver abscess prevalence and severity, however numerical differences were observed (23.1, 26.6, and 35.4% for MDGS, SBM, and SBM-SBH, respectively). Studies suggest protein concentration and source have little effect on the development of liver abscesses in finishing cattle (Haskins et al., 1967; Wise et al., 1968). Furthermore, liver abscesses are most often associated with cattle fed diets high in readily-fermentable carbohydrates (Amachawadi and Nagaraja, 2016). Therefore, the numerical differences observed in liver abscess prevalence and severity may be related to starch and NDF source and content rather than protein source.

SUMMARY

In this trial, feeding supplemental protein sources with enhanced diet conditioning attributes and greater concentrations of ruminally undegradable protein in the form of MDGS provided no advantage to cattle performance when measured over the entire experiment. Soybean meal did support greater gains and increased feed efficiency during the first 21 d. Observed growth performance was in close agreement with current estimates for maintenance and retained energy. Therefore, protein source decisions between MDGS and SBM can be based upon price per delivered crude protein and differences in diet costs.

LITERATURE CITED

Amachawadi, R. G., Nagaraja, T. G. 2016. Liver abscesses in cattle: A review of incidence in Holsteins and of bacteriology and vaccine approaches to control in feedlot cattle. Journal of Animal Science, **94**(4): 1620–1632. doi: 10.2527/jas.2015-0261

Anderson, S. J., Merrill, J. K., McDonnell, M. L., Klopfenstein, T. J. 1988. Digestibility and Utilization of Mechanically Processed Soybean Hulls by Lambs and Steers. Journal of Animal Science, **66**(11): 2965-2976. doi: 10.2527/jas1988.66112965x

AOAC. 2012. Official methods of analysis. 19th ed. Assoc. Off. Anal. Chem., Arlington, VA.

AOAC. 2016. Official methods of analysis. 20th ed. Assoc. Off. Anal. Chem., Arlington, VA

Arnall, B., Baughman, T., Damincone, J., Lofton, J., Royer, T., Warren, J. 2020. Soybean Production Guide [Online] Available: https://extension.okstate.edu/fact-sheets/soybean-production-guide.html [2023 Sept. 15]

Bittner, C. J., Nuttelman, B. L., Schneider, C. J., Burken, D. B., Johnson, L. J., Mader, T. L., Klopfenstein, T. J., Erickson, G. E. 2016. Effects of increasing soybean hulls in finishing diets with wet or modified distillers grains plus solubles on performance and carcass characteristics of beef steers. The Professional Animal Scientist, **32**(6): 777–783. doi: 10.15232/pas.2016-01507

Firkins, J. L., Berger, L. L., Fahey, Jr., G. C. 1985. Evaluation of wet and dry distillers grains and wet and dry corn gluten feeds for ruminants. Journal of Animal Science, **60**(3); 847-860. doi: doi.org/10.2527/jas1985.603847x

Fox, D. G., Black, J. R. 1984. A system for predicting body composition and performance of growing cattle. Journal of Animal Science, **58**(3): 725–739. doi: 10.2527/jas1984.583725x

Guiroy, P., Tedeschi, L., Fox, D., Hutcheson, J. 2002. The effects of implant strategy on finished body weight of beef cattle. Journal of Animal Science, **80**(7):1791- 1800. doi: 10.2527/2002.8071791x

Heiderscheit, K. J., Hansen, S. L. 2020. Effect of rumen-protected lysine on growth performance, carcass characteristics, and plasma amino acid profile in feedlot steers. Translational Animal Science, **4**(3): txaa128. doi: 10.1093/tas/txaa128

Hoffman, L. A., Baker, A. 2011. Estimating the substitution of distillers' grains for corn and soybean meal in the U.S. feed complex. U.S. Department of Agriculture [Online] Available: https://www.ers.usda.gov/publications/pub-details/?pubid=36472 [2024 Feb. 20]

Haskins, B. R., Wise, M. B., Craig, H. B., Barrick, E. R. 1967. Effects of Levels of Protein, Sources of Protein and an Antibiotic on Performance, Carcass Characteristics, Rumen Environment and Liver Abscesses of Steers Fed All-Concentrate Rations. Journal of Animal Science, **26**(2): 430–434. doi: 10.2527/jas1967.262430x

Huls, T. J., Bartosh, A. J., Daniel, J. A., Zelinsky, R. D., Held, J., Wertz-Lutz, A. E. 2006. Efficacy of Dried Distiller's Grains with Solubles as a Replacement for Soybean Meal. Small Ruminant Research, **201**: 106411. doi: 10.1016/j.smallrumres.2021.106411

Huuskonen, A., Huhtanen, P., Joki-Tokola, E. 2014. Evaluation of protein supplementation for growing cattle fed grass silage-based diets: a meta-analysis. Animal (Cambridge, England), **8**(10): 1653–1662. doi: 10.1017/S1751731114001517

Klemesrud, M. J., Klopfenstein, T. J., Stock, R. A., Lewis, A. J., Herold, D. W. 2000. Effect of dietary concentration of metabolizable lysine on finishing cattle performance. Journal of Animal Science, **78**(4): 1060–1066. doi: 10.2527/2000.7841060x

Leonardi, C., Giannico, F., Armentano, L. E. 2005. Effect of water addition on selective consumption (sorting) of dry diets by dairy cattle. Journal of Dairy Science, **88**(3): 1043-1049. doi: 10.3168/jds.S0022-0302(05)72772-7.

Ludden, P. A., Cecava, M. J., Hendrix, K. S. 1995. The value of soybean hulls as a replacement for corn in beef cattle diets formulated with or without added fat. Journal of Animal Science, **73**(9): 2706–2711. doi: 10.2527/1995.7392706x

Mateo, K. S., Tjardes, K. E., Wright, C. L., Koger, T. J., Rops, B. D. 2004. Evaluation of Feeding Varying Levels of Wet Distillers Grains with Solubles as Compared to Dry Distilelrs Grains with Solubles to Finishing Steers. South Dakota Beef Report, 2004. Paper 4. http://openprairie.sdstate.edu/sd_beefreport_2004/4

Miller-Cushon, E. K., DeVries, T. J. 2009. Effect of dietary dry matter concentration on the sorting behavior of lactating dairy cows fed a total mixed ration. Journal Dairy of Science, **92**(7): 3292–3298. doi: 10.3168/jds.2008-1772

Miller-Cushon, E. K., DeVries, T. J. 2017. Feed sorting in dairy cattle: Causes, consequences, and management. Journal of Dairy Science, **100**(5): 4172–4183. doi: 10.3168/jds.2016-11983

Murphey, C., Hallett, D., Tyler, W., Pierce Jr., J. 1960. Estimating yields of retail cuts from beef carcasses. Journal of Animal Science, **19**(Suppl 1):1240. doi: 10.2527/jas1960.1941216x

NASEM (National Academies of Sciences, Engineering, and Medicine). 2016. Nutrient Requirements of Beef Cattle. Revised 8th Ed.. National Academy Press, Washington, DC. doi: 10.17226/19014

Pagano, M. C., Miransari, M. 2016. The importance of soybean production worldwide. Abiotic and Biotic Stresses in Soybean Production. 1-26 doi: 10.1016/B978-0-12-801536-0.00001-3

Pittaluga, A. M., Clark, C., Relling, A. E. 2021. Effect of protein source and nonroughage NDF content in finishing diets of feedlot cattle fed free-choice hay on growth performance and carcass characteristics. Translational Animal Science, **5**(4): txab224. doi: 10.1093/tas/txab224

Preston, R. L. 2016. Feed Composition Table. BEEF Magazine [Online] Available: https://www.beefmagazine.com/sites/beefmagazine.com/files/2016-feedcomposition-tablesbeef-magazine.pdf [2023 Oct. 13]

Shen, J., Li, Z., Yu, Z., Zhu, W. 2020. Effects of dietary replacement of soybean meal with dried distillers grains with solubles on the microbiota occupying different ecological niches in the rumen of growing Hu lambs. Journal of Animal Science and Biotechnology. **11**(1):93. Doi: 10.1186/s40104-020-00499-2

Sorensen, R. J., Stewart, S. S., Jones, C. K., Crane, A. R., Lattimer, J. M. 2021. Efficacy of corn dried distillers grains with solubles as a replacement for soybean meal in Boer-

cross goat finishing diets. Small Ruminant Research, **201**: 106411. doi: 10.1016/j.smallrumres.2021.106411

Suriyapha, C., Suntara, C., Wanapat, M., Cherdthong, A. 2022. Effects of Substituting Agro-Industrial By-Products for Soybean Meal on Beef Cattle Feed Utilization and Rumen Fermentation. Scientific Reports, **12**(1): 21630-21630. doi: 10.1038/s41598-022-26191-1

Teixeira, P. D., Tekippe, J. A., Rodrigues, L. M., Ladeira, M. M., Pukrop, J. R., Kim, Y. H. B., Schoonmaker, J. P. 2019. Effect of ruminally protected arginine and lysine supplementation on serum amino acids, performance, and carcass traits of feedlot steers. Journal of Animal Science, **97**(8): 3511–3522. doi: 10.1093/jas/skz191

Trenkle, A. 1998. Substituting Wet Distillers Grains or Condensed Distillers Solubles for Corn Grain in Finishing Diets for Yearling Heifers. Iowa State University Animal Industry Repository., Leaflet R1451

USDA. 1997. Official United States Standard for Grades of Beef Carcasses. Agric. Marketing, USDA Washington (DC).

USDA. 2024. Grains and Oilseeds Outlook for 2024 [Online] Available: https://www.usda.gov/sites/default/files/documents/2024AOF-grains-oilseeds-outlook.pdf#:~:text=Soybean%20oil%20for%20biofuel%20is%20expected%20to%20grow,flat%20while%20biofuel%20absorbs%20the%20growth%20in%20supplies [2024 Feb. 21]

Wagner, J. J., Engle, T. E., Bryant, T. C. 2010. effect of rumen degradable and rumen undegradable intake protein on feedlot performance and carcass merit in heavy

yearling steers. Journal of Animal Science, **88**(3): 1073–1081. doi: 10.2527/jas.2009-2111

Wise, M. B., Harvey, R. W., Haskins, B. R., Barrick, E. R. 1968. Finishing Beef Cattle on All-Concentrate Rations. Journal of Animal Science, **27**(5): 1449-1461. doi: 10.2527/jas1968.2751449x

Zinn, R. A., Barreras, A., Owens, F. N., Plascencia, A. 2008. Performance by feedlot steers and heifers: Daily gain, mature body weight, dry matter intake, and dietary energetics. Journal of Animal Science, **86**(10): 2680-2689. doi: 10.2527/jas.2007-0561.

Zinn, R. A., Shen, Y. 1998. An evaluation of ruminally degradable intake protein and metabolizable amino acid requirements of feedlot calves. Journal of Animal Science, **76**(5): 1280-1289. doi: 10.2527/1998.7651280x

TABLES

Table 2.1. Diet formulations and nutrient compositions[a]

	Treatment[b]								
	d 1 to 45			d 46 to 105			d 106 to 118		
Item[c]	MDGS	SBM	SBM-SBH	MDGS	SBM	SBM-SBH	MDGS	SBM	SBM-SBH
Ingredient Composition, %									
DRC	68.40	72.78	67.97	68.48	74.32	68.27	73.49	79.09	73.17
MDGS	14.51	0.00	0.00	14.99	0.00	0.00	14.51	0.00	0.00
SBM	0.00	9.62	8.52	0.00	9.21	9.22	0.00	8.98	8.99
SBH	0.00	0.00	5.74	0.00	0.00	6.03	0.00	0.00	5.89
Ryelage	13.22	13.81	13.94	0.00	0.00	0.00	0.00	0.00	0.00
Corn Silage	0.00	0.00	0.00	12.41	12.37	12.38	0.00	0.00	0.00
Sorghum Silage	0.00	0.00	0.00	0.00	0.00	0.00	7.97	7.93	7.94
LS[d]	3.87	3.79	3.84	4.11	4.10	4.10	4.03	4.01	4.01
Nutrient Composition[e]									
DM, %	64.97	70.41	70.25	64.44	71.51	71.48	67.61	75.38	75.32
CP, %	12.52	13.25	13.09	12.23	12.27	12.64	11.92	11.98	12.34
RDP[f], %	6.90	8.35	8.23	6.34	7.55	7.72	6.81	8.00	8.17
NDF, %	18.31	15.56	18.66	16.37	13.21	16.41	15.39	12.32	15.45
ADF, %	9.12	7.87	10.46	7.65	6.12	8.84	6.91	5.42	8.08
Ash, %	5.23	5.00	5.19	4.97	4.70	4.91	4.82	4.56	4.77
EE, %	4.65	4.02	4.01	4.71	4.08	4.04	4.64	4.03	3.99
NEm, Mcal/kg[f]	2.04	2.02	2.00	2.09	2.07	2.05	2.08	2.07	2.05
NEg, Mcal/kg[f]	1.35	1.33	1.31	1.41	1.40	1.38	1.40	1.38	1.36

[a] All values except dry matter are on a DM basis

[b] MDGS fed at 15% diet DM (MDGS), MDGS replaced by either soybean meal and corn (9 and 6% of DM, respectively; SBM), MDGS replaced by soybean meal and soyhull pellets (9 and 6% of DM, respectively; SBM-SBH).

[c] DRC = dry rolled corn; MDGS = modified distillers grains plus solubles; SBM = soybean meal; SBH = soybean hull pellets; LS = liquid supplement; DM = dry matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; EE = ether extract; NEm = net energy for maintenance; NEg = net energy for gain

[d] Liquid supplement contained (DM basis): 27.0% CP, 20.154% non-protein nitrogen, 0.855 Mcal/kg of NEm, 0.579 Mcal/kg of NEg, 0.316% ether extract, 20.273% total sugars, 58.823% ash, 16.923% calcium, 0.40% P, 1.538% K, 0.255% Mg, 7.935% NaCl, 3.415% Na, 0.493% S, 4.615 ppm Co, 250.00 ppm Cu, 40.0 ppm I, 50.0 ppm EDDI, 243.067 ppm Fe, 500.00 ppm Mn, 4.00 ppm Se, 2,253.846 ppm Zn, 16,329.31 IU/kg Vitamin A, 113.40 IU/kg Vitamin E, and 750.769 g/ton monensin sodium

[e] Tabular NE from Preston (2016) and actual nutrient compositions

[f] Calculated using values from NASEM (2016) and Preston (2016)

Table 2.2. Dietary amino acid content[a].

	Treatment[b]								
	d 1 to 45			d 46 to 105			d 106 to 118		
Amino Acids, g/d	MDGS	SBM	SBM-SBH	MDGS	SBM	SBM-SBH	MDGS	SBM	SBM-SBH
Arginine	59.98	86.21	82.79	74.75	101.08	104.08	79.44	104.20	105.14
Histidine	36.20	41.21	39.95	46.45	49.68	50.97	48.51	51.01	51.12
Isoleucine	48.61	60.78	58.81	61.56	71.97	74.66	62.03	71.41	72.10
Leucine	151.99	149.76	143.14	201.00	187.22	188.09	210.56	194.10	189.93
Lysine	41.28	66.89	66.12	51.28	78.12	83.70	50.89	76.57	80.19
Methionine	25.92	26.05	24.91	34.16	32.39	32.63	34.90	32.68	32.03
Phenylalanine	66.51	76.82	73.85	83.65	90.65	92.59	86.31	92.00	91.56
Threonine	50.20	58.59	56.84	64.24	70.20	72.59	64.36	69.35	69.77
Tryptophan	11.34	16.36	16.09	13.53	18.49	19.64	14.20	18.88	19.55
Valine	65.95	74.57	72.34	83.08	88.01	90.87	83.53	87.25	87.55

[a] Calculated from NASEM, 2021

[b] MDGS fed at 15% diet DM (MDGS), MDGS replaced by either soybean meal and corn (9 and 6% of DM, respectively; SBM), MDGS replaced by soybean meal and soyhull pellets (9 and 6% of DM, respectively; SBM-SBH).

Table 2.3. Influence of replacing modified distillers grains (MDGS) with soybean meal or soybean meal (SBM) and soyhulls (SBM-SBH) on growth performance responses through d 118 dead and removals excluded[a]

	Treatment[b]				*P*-values		
Item	MDGS	SBM	SBM-SBH	SEM[f]	Treatment effect	SBM effect[c]	Starch effect[d]
Pens, n	8	8	8				
Steers, n	79	79	80				
Initial BW[a], kg	437	434	434				
d 1 to d 21							
BW d 21[a], kg	471	491	489	2.0	0.01	0.01	0.01
ADG, kg	1.62	2.70	2.60	0.093	0.01	0.01	0.01
DMI, kg	10.05	10.99	10.59	0.067	0.01	0.01	0.01
G:F	0.161	0.246	0.245	0.0080	0.01	0.01	0.01
F:G[e]	6.39	4.10	4.10	-	-	-	-
d 22 to d 49							
BW d 49[a], kg	545	555	553	2.4	0.02	0.01	0.05
ADG, kg	2.65	2.31	2.32	0.090	0.03	0.01	0.15
DMI, kg	12.36	12.34	12.56	0.100	0.26	0.46	0.36
G:F	0.214	0.187	0.185	0.007	0.01	0.01	0.16
F:G[e]	4.72	5.44	5.44	-	-	-	-
d 50 to d 77							
BW d 77[a], kg	619	632	628	4.0	0.12	0.06	0.12
ADG, kg	2.66	2.74	2.66	0.115	0.87	0.80	0.60
DMI, kg	14.20	14.39	14.58	0.166	0.30	0.18	0.99
G:F	0.190	0.190	0.182	0.0068	0.71	0.88	0.53
F:G[e]	5.26	5.26	5.49	-	-	-	-
d 78 to d 118							
BW d 118[a], kg	690	695	687	3.8	0.33	0.80	0.17
ADG, kg	1.72	1.55	1.44	0.085	0.11	0.05	0.74
DMI, kg	14.67	14.41	14.27	0.174	0.27	0.13	0.76

G:F	0.117	0.108	0.101	0.0054	0.15	0.07	0.80
F:G[e]	8.55	9.26	9.90	-	-	-	-
Cumulative (live-basis)							
ADG, kg	2.15	2.22	2.15	0.032	0.22	0.37	0.09
DMI, kg	13.19	13.30	13.28	0.096	0.68	0.39	0.57
G:F	0.163	0.167	0.162	0.0054	0.15	0.07	0.80
F:G[e]	6.13	5.99	6.17	-	-	-	-
Cumulative (HCW/0.625)							
Final BW, kg	684	679	672	3.9	0.11	0.09	0.81
ADG, kg	2.09	2.08	2.01	0.032	0.22	0.25	0.56
G:F	0.159	0.156	0.152	0.0023	0.13	0.11	0.73
F:G[e]	6.29	6.41	6.58	-	-	-	-
Applied Energetics[g]							
NEm[h], Mcal/kg	2.05	2.04	2.00	0.019	0.19	0.22	0.55
NEg[i], Mcal/kg	1.39	1.38	1.34	0.017	0.19	0.22	0.55
O/E[j] NEm	1.00	1.00	0.99	0.010	0.92	0.84	0.84
O/E[j] NEg	1.01	1.01	1.00	0.012	0.88	0.97	0.66
Retained Protein, g/d	206.3	206.9	202.1	-	-	-	-

[a] A 4% pencil shrink was applied to BW measures to account for gastrointestinal tract fill.
[b] MDGS fed at 15% diet DM (MDGS), MDGS replaced by either soybean meal and corn (9 and 6% of DM, respectively; SBM), MDGS replaced by soybean meal and soyhull pellets (9 and 6% of DM, respectively; SBM-SBH).
[c] MDGS vs. SBM and SBM-SBH
[d] SBM vs. MDGS and SBM-SBH
[e] Calculated as: 1/G:F
[f] Pooled SEM
[g] Determined from carcass-adjusted growth performance
[h] Net energy for maintenance
[i] Net energy for gain
[j] Observed to Expected

Table 2.4. Effect of replacing modified distillers grains with soybean meal or soybean meal and soyhulls on steer carcass characteristics[a]

	Treatment[a]				*P*-value		
Item[b]	MDGS	SBM	SBM-SBH	SEM	Treatment effect	SBM effect[c]	Starch effect[d]
Carcass Traits							
HCW, kg	427	425	420	2.4	0.11	0.09	0.81
DP[e], %	61.96	61.14	61.23	0.291	0.13	0.05	0.22
RF, cm	1.55	1.57	1.57	0.041	0.90	0.69	0.99
REA, cm^2	90.00	88.39	88.13	0.710	0.17	0.07	0.42
Marbling[f]	535	549	531	10.9	0.51	0.74	0.27
Calculated YG	3.65	3.72	3.69	0.062	0.74	0.47	0.57
RY, %	48.72	48.58	48.63	0.128	0.73	0.46	0.56
EBF[g], %	32.49	32.72	32.51	0.279	0.81	0.71	0.53
AFBW[g], kg	596	587	584	3.8	0.11	0.05	0.60
Quality Grade Distribution, %							
Select	6.4	3.9	8.8	-	0.70		
Low Choice	26.9	26.0	28.8				
Average Choice	42.3	42.9	40.0				
High Choice	18.0	23.4	18.8				
Prime	6.4	3.9	3.8				
Yield Grade Distribution, %							
1	1.3	1.3	0.0		0.70		
2	24.4	15.2	18.3				
3	52.6	62.0	53.7				
4	21.8	20.3	26.8				
5	0.0	1.3	1.2				
Liver Abscess Prevalence, %							
Normal	76.9	73.4	64.6		0.11		
A-	11.5	13.9	11.0				
A	5.1	1.3	6.1				
A+	6.4	11.4	18.3				

[a] MDGS fed at 15% diet DM (MDGS), MDGS replaced by either soybean meal and corn (9 and 6% of DM, respectively; SBM), MDGS replaced by soybean meal and soyhull pellets (9 and 6% of DM, respectively; SBM-SBH).
[b] HCW = hot carcass weight; DP = dressing percent; REA = ribeye area; RF = rib fat; RY = retail yield; EBF = empty body fat; AFBW = carcass-adjusted final body weight
[c] MDGS vs. SBM and SBM-SBH
[d] SBM vs. MDGS and SBM-SBH
[e] Calculated as: (HCW/Final BW shrunk 4%) × 100.
[f] $Small^{00}$ = 400
[g] Calculated according to Guiroy et al. (2002).

CHAPTER III: INCREASED DIETARY RUMEN DEGRADABLE PROTEIN FROM SOYBEAN MEAL IMPROVED GROWTH PERFORMANCE BUT INCREASED LIVER ABSCESS SEVERITY IN FINISHING BEEF STEERS

ABSTRACT

The objective of this study was to determine if partial or complete replacement of dried distillers grains plus solubles (DDGS) with solvent-extracted soybean meal (SBM) in high-moisture ensiled corn diets influences growth performance, efficiency of dietary net energy utilization, sera urea-N (SUN) concentrations, or carcass traits in finishing beef steers. Continental × British steers [n = 189; initial shrunk body weight (BW) = 381 ± 37.1 kg] were used in a 139-d experiment with three treatments: DDGS fed at 20% DM (15.4% CP, 8% RDP, and 1.90% NPN; DDGS), SBM replacing 50% of DDGS (16.4% CP, 9% RDP, and 0.96% NPN; SBM50), and SBM replacing 100% of DDGS (17.4% CP, 10% RDP, and 0.05% NPN; SBM100). Steers (n = 189) were initially weighed and allotted to one of 24 pens (n = 7 or 8 steers per pen; 8 pens per treatment) at the Ruminant Nutrition Center located near Brookings, SD. Whole blood was collected and harvested as sera on d 77, 105, and 139 to determine circulating concentrations of sera urea-N. Data were analysed as a randomized complete block design using the GLIMMIX procedure of SAS 9.4 with treatment and block (initial BW) as fixed effects; pen was the experimental unit. Treatment effects were evaluated for linear and quadratic components by the method of orthogonal polynomials. Sera urea-N was analyzed as repeated measures. On a live basis, feeding SBM linearly increased final BW ($P = 0.03$) but did not affect DMI ($P \geq 0.33$). Dietary treatment tended to quadratically affect ADG ($P = 0.09$) and G:F ($P =$

0.06) with the greatest positive effects in SBM50 fed cattle. Carcass adjusted performance values were calculated by dividing hot carcass weight (HCW) by a common dressing percentage of 0.625. No differences were noted for carcass adjusted final BW (cFBW), ADG, DMI, or feed efficiency ($P \geq 0.18$). Dietary treatment tended to quadratically affect G:F ($P = 0.10$) and SBM increased the apparent efficiency of energy capture (Linear; $P = 0.01$). The total and partial substitution NEg values were 17.0 and 27.5% greater than DDGS respectively. Dietary treatment had no effect ($P \geq 0.22$) on HCW, rib fat, or marbling score. Complete replacement of DDGS with SBM linearly increased rib eye area (REA) by 1% ($P = 0.02$), but linearly decreased dressing percentage ($P = 0.03$). Distribution of USDA Quality or Yield grades were unaffected by treatment ($P \geq 0.36$). Feeding SBM as a replacement of DDGS altered the distribution of liver scores. Steers from SBM100 had fewer livers classified as normal and a greater proportion of livers classified as severely (A+ or Greater) abscessed ($P = 0.05$). No treatment × day interaction was observed for sera urea-N ($P = 0.20$). However, day ($P < 0.01$) and treatment ($P < 0.01$) effects were observed. Throughout the duration of the trial the SBM100 treatment maintained greatest sera urea-N concentrations, the SBM50 treatment being intermediate, and the DDGS treatment had least concentrations of sera urea-N ($P < 0.01$). Further, sera urea-N concentrations increased overtime from d 77 to d 139 ($P < 0.01$). In this experiment, replacement of DDGS with SBM increased REA and tended to decrease DP and had a quadratic tendency to improve feed conversion with no other observed effects on carcass adjusted growth performance or carcass traits.

INTRODUCTION

Traditionally, corn-milling co-products are used as a standard feed ingredient in American feedlots, whereas oilseeds are rarely used. The average inclusion of distillers in American feedlot diets is 19.9% dietary DM (Asem-Hiablie et al., 2016) with 86.7% of nutritionists choosing to use WDGS or DDGS as their primary grain by-product (Samuelson et al., 2016). When comparing soybean meal (SBM) and DDGS, SBM is more consistent in nutrient composition over DDGS because of continual developments in fractionation techniques of ethanol plants (Fontaine et al., 2007). Further, because of differing processing methods of SBM and DDGS, the rumen degradability of protein is approximately 30% greater in SBM than DDGS (Mjourn et al., 2010).

When considering RDP in diet formulations, 62.5% of consulting nutritionists do not formulate for RDP according to Samuleson et al. (2016). However, Cooper et al., (2002) reported that greatest growth performance responses were achieved at 10.2% dietary RDP in high moisture corn-based diets, supplied largely by urea. Often, RDP is supplied in finishing diets by urea because of better accessibility and cost effectiveness. However, asynchronization between fermentable energy availability and ammonia production in the rumen negatively affects microbial protein synthesis (Salami et al., 2021) consequently reducing the availability of metabolizable protein reaching the small intestine. Soybean meal degrades at a more constant rate within the rumen, peaking three to five hours post feeding compared to the much more rapid solubility of urea, which peaks 1-2 h after a meal (Owens and Zinn, 1988).

Objectives of this experiment were to determine if partial or complete substitution of dried distillers grains plus solubles with soybean meal influences growth performance,

carcass characteristics, or sera urea nitrogen measures in finishing beef steers. Our hypothesis was that soybean meal could be substituted for dried distillers grains plus solubles in finishing diets and that increased dietary inclusion rates would result in positive or no effects on growth performance, feed efficiency, and carcass characteristics.

MATERIALS AND METHODS

Institutional Animal Care and Use Approval

All experimental protocols were approved by the South Dakota State University Institutional Animal Care and Use Committee (Approval Number: 2311-008E).

Animals, Initial Processing, and Study Initiation

Continental × British crossbred steers (n = 189) were utilized in a 139-d feedlot finishing experiment at the South Dakota State University Ruminant Nutrition Center (RNC) in Brookings, SD. All steers used in the study had previously been enrolled in an unrelated receiving phase experiment conducted at the RNC. Prior to the initiation of the current study (d -58), steers had been vaccinated for viral respiratory pathogens (Bovi-Shield Gold 5, Zoetis; Parsipanny, NJ) and clostridial species (Ultrabac 7/Somubac, Zoetis), and administered a pour on moxidectin (Cydectin, Bayer Healthcare LLC, Shawnee Mission, KS) for internal and external parasites. On d -4 steers were individually weighed for allotment purposes. On d 0, steers were weighed and allotted to study pens and test diets were initiated. The combined d -4 and d 0 BW were used as the initial BW [initial shrunk (4%) BW = 381 ± 37.1 kg]. Steers were administered a

steroidal implant on d 35 (200 mg trenbolone acetate and 28 mg estradiol benzoate; Synovex-PLUS, Zoetis).

Experimental Design and Treatments

Three treatments were used in a randomized complete block design using 24 pens (n = 8 pens/treatment; n = 7 or 8 steers/pen). Each pen was assigned to 1 of 3 dietary treatments: 1) a finishing diet based upon DDGS as the protein source that contained zero SBM (**DDGS**; 15.4% CP, 8% RDP, and 1.90% NPN), 2) a finishing diet that contained SBM at 50% replacement of DDGS (**SBM50**; 16.4% CP, 9% RDP, and 0.96% NPN), 3) a finishing diet that contained SBM at 100% replacement of DDGS (**SBM100**; 17.4% CP, 10% RDP, and 0.05% NPN). The SBM evaluated in treatments 2 and 3 were included in the diet at approximately 10% or 20% of diet dry matter (DM), respectively.

Diets and Intake Management

Cattle were fed twice daily at 0800 h and 1400 h and bunks were visually appraised at 0700 h to determine daily feed allowances. Bunks were managed according to a slick bunk management system to avoid feed carry-over. Feed was manufactured in a commercial mixer wagon (2.35 m^3; Roto-MIX, Dodge City, KS; scale readability ± 0.454 kg). Over a period of 25 d, steers were transitioned from a 78% concentrate diet to a 91% concentrate diet.

Individual ingredient samples were collected weekly, and DM was calculated following drying in a 60°C forced air oven until no weight change to calculate dry matter intake (DMI). Actual diet formulation was based upon weekly DM analyses and

corresponding feed batching records. Diets were fortified to provide vitamins and minerals to meet or exceed nutrient requirements and provided monensin sodium at 30 g/ton of diet DM (NASEM, 2016). Diets presented in Table 3.1 are actual DM formulation, nutrient concentrations, and tabular energy values (Preston, 2016). Weekly ingredient samples were stored in a freezer at -20 ºC until nutrient analyses were completed. After DM determination (method no. 935.29; AOAC, 2012), weekly samples from each ingredient were analyzed for N (method no. 968.06; AOAC, 2016; Rapid Max N Exceed; Elementar; Mt. Laurel, NJ), and ash (method no. 942.05; AOAC, 2012). When necessary, orts were collected, weighed, and dried in a forced air oven at 60°C for 24 h to determine DM content. The dry matter intake (DMI) of pen was adjusted to reflect the total DM delivered to each pen after subtracting dry orts for each period.

Growth Performance Collection and Carcass Trait Determination

Steers were individually weighed on d -4, 0, 35, 77, 105, and 139 (trial termination). Body weights were measured prior to morning feeding and a 4% pencil shrink was applied to all BW measures to account for gastrointestinal tract fill. Cumulative growth performance was calculated on a live and carcass-adjusted basis. Average daily gain (ADG) was calculated as the difference between final BW (FBW) and initial shrunk BW, divided by days on feed (139 d). Efficiency of weight gain (G:F) was calculated by dividing ADG by daily DMI. Dry matter intake was tabulated at weekly intervals and summarized by interim period.

Steers were harvested after 139 d on feed when appraised to have 1.5 cm of fat at the 12^{th} rib (RF). Steers were shipped in the afternoon following final BW determination and harvested the following day at a commercial abattoir. Steers were comingled at the time

of shipping until time of harvest at approximately 0700 h in the day after shipping. At time of harvest, hot carcass weight and liver abscess data was collected, and video image data was obtained from the abattoir for rib eye area (REA), rib fat (RF), marbling scores, and USDA Quality and Yield grades. Liver scores were determined by a trained technician and classified according to the Elanco Liver Scoring System: normal (no abscesses), A- (1 or 2 small abscesses or abscess scars), A (2 to 4 well-organized abscesses less than 2.54 cm in diameter), or A+ (1 or more large active abscesses greater than 2.54 cm in diameter with inflammation of surrounding tissue). Dressing percentage (DP) was calculated as HCW/(final BW × 0.96). A common kidney, pelvic, and heart (KPH) fat percentage of 2.5% was applied to the USDA regression equation (USDA, 1997). Estimated empty body fat (EBF) percentage and final BW at 28% EBF (AFBW) were calculated from observed carcass traits (Guiroy et al., 2002), as well as estimated proportion of closely trimmed boneless retail cuts from carcass round, loin rib, and chuck [Retail Yield (RY); Murphey et al., 1960].

Carcass-adjusted growth performance was used to calculate performance-based dietary NE to determine the efficiency of dietary NE utilization. Performance-adjusted NE was calculated from daily energy gain (EG; Mcal/d) using the following equation (NASEM, 2016):

$$EG = ADG^{1.097} \times 0.0557BW^{0.75},$$

where BW is the mean equivalent metabolic shrunk BW (kg) calculated as shrunk BW × (478/AFBW), where AFBW is the adjusted final body weight.

Maintenance energy (EM; Mcal/d) was calculated using the following model:

$$EM = 0.077 \times BW^{0.75}.$$

Dry matter intake (DMI) is related to energy requirements and dietary NEm (Mcal/kg) according to the following equation: DMI = EG/(0.877NEm – 0.41), and can be resolved for estimation of dietary NEm by means of the quadratic formula (Zinn and Shen, 1998):

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2c},$$

where x = NEm, Mcal/kg, a = -0.41EM, b = 0.877EM + 0.41DMI + EG, c = -0.877DMI.

Dietary net energy for gain (NEg; Mcal/d) was determined from NEm using the following equation (Zinn et al., 2008): NEg = 0.877NEm – 0.41.

The comparative NEm and NEg values SBM100 was estimated using the replacement and substitution technique. Given that the NEm and NEg value of DDGS is 2.21 Mcal/kg and 1.50 Mcal/kg respectfully, the replacement NEm and NEg values for SBM can be determined:

SBM NEm = [(SBM100 NEm – DDGS diet NEm) ÷ (SBM100 inclusion] + 2.21 and SBM ingredient NEg = [(SBM100 NEg – DDGS diet NEg) ÷ (SBM100 inclusion] + 1.50,

where inclusion of SBM100 was 0.1925 on a DM basis.

Finally, in the case of the substitution technique, the NEm and NEg values for SBM are determined as follows:

NE SBM = (NE (SBM100 diet – 0.8075 NE DDGS diet)/ 0.1925,

where 0.8075 and 0.1925 are the proportions of DDGS diet and SBM, respectively.

Retained energy (RE) was calculated based on the following (NASEM, 2016):

RE (Mcal/d) = $0.0635 \times EBW^{0.75} \times EBG^{1.097}$.

Retained protein (RP, g/d) was calculated using the following model (NASEM, 2016):

$RP = SWG \times \{268 - [29.4 \times (RE/SWG)]\}$

Sera Urea Nitrogen Determination

Whole blood was collected and then harvested as sera on d 77, 105, and 139 relative to trial initiation. Sentinel steers (n = 2 steers/pen; 16 steers/treatment) identified prior to d 77 were used for sera urea nitrogen (SUN) determination. The sentinel steers were selected from each pen based on the average pen body weight on d 36. The two steers/pen with a body weight closest to the home pen mean were selected for blood collection. Whole blood was collected from the jugular vein into 15 mL nonadditive evacuated tubes and allowed to clot for 4 h at room temperature and subsequently centrifuged at 3000 × g for 20 minutes to harvest sera. The collected sera was froze at -20°C until end of trial to be used to quantify circulating concentrations of SUN. The quantification of circulating SUN concentration was determined on a microplate spectrometer in triplicate 5 µL determinations, according to methods described by Fawcett and Scott (1960). The standard curve constructed for the SUN assay was between 0 and 40.0 mg/dL. All samples were analyzed in triplicate and samples were considered for reruns if the coefficient of variation among the absorbance values within triplicate determinations was greater than 5%.

Management of Pulls and Removals

All steers removed from their treatment pen for health evaluation were treated accordingly and transferred to an individual hospital pen if further monitoring was justified. During relocation to the hospital pen, the appropriate amount of feed from the home pen was removed and transferred to the hospital pen. Instances where the steer in the hospital pen was returned to the home pen, its feed remained credited to the home pen. If the steer did not return to their home pen, all feed deliveries to the hospital pen was deducted from the feed intake record for that pen back to the date the steer was hospitalized. Steers that were removed from the study or that had died in pen during the study were assumed to have consumed feed equal to the pen mean DMI up to the point of removal or death. Three steers (from SBM50) died or were removed from the study for reasons unrelated to dietary treatment, thus all data are reported on a deads and removals excluded basis.

Statistical Analysis

Growth performance, carcass traits, and efficiency of dietary energy were analysed as a randomized complete block design (RCBD) using the GLIMMIX procedure of SAS 9.4 (SAS Inst. Inc, Cary, NC) with pen as the experimental unit. The model included fixed effects of block (initial body weight) and dietary treatment. Orthogonal contrasts were used to determine linear and quadratic effects. Distributions of USDA Quality and Yield grades, and liver abscess prevalence and severity were analysed as multinomial distributions using the GLIMMIX procedure of SAS 9.4 to identify differences in the distributions among treatments. Sera urea-N was analyzed as repeated

measures. Individual animal was the experimental unit for categorical outcome data with the same random and fixed effects used in the model as previously described. Dry matter intake was analysed using the GLIMMIX procedure of SAS 9.4 using repeated measures and least squares means were generated using the LSMEANS statement of SAS 9.4. For all analyses, an α of 0.05 determined significance and an α of 0.06 to 0.10 was considered a tendency.

RESULTS

Growth Performance

In the first 35 d of the study, SBM fed cattle had greater ADG (Linear; $P = 0.01$; Table 3.3), but treatment did not affect DMI ($P = 0.39$). Therefore, feeding SBM as a replacement of DDGS linearly increased G:F in the first 35 d ($P = 0.01$). Interim data from d 36 to 77 did not show a continuation of these observations. During this period, ADG and G:F were unaffected by treatment ($P \geq 0.33$) while DMI was linearly increased in steers fed DDGS ($P = 0.03$). Greater interim BW was carried over in the SBM fed steers from the first 35 d of study (Linear; $P = 0.03$). Cumulatively, steers fed SBM had greater FBW (Linear; $P = 0.03$), ADG (Linear; $P = 0.05$), and G:F (Linear; $P = 0.01$). Dry matter intake was unaffected by soybean meal substitution ($P = 0.60$). At the same level of intake and greater ADG, steers fed SBM exhibited improved gain efficiency than those fed exclusively DDGS as their protein source (Linear; $P = 0.02$).

Dietary treatment did not influence carcass-adjusted final BW ($P = 0.32$), ADG ($P = 0.77$), or DMI ($P = 0.38$). A tendency for greater G:F (Quadratic; $P = 0.10$) was observed in steers fed SBM50.

Observed Dietary Net Energy

Feeding SBM linearly and quadratically increased both apparent dietary net energy values for both maintenance and gain ($P = 0.03$) and the ratio of observed to expected dietary energy ($P \leq 0.04$). The replacement and substitution NEg values for SBM were 27.5 and 17.0% greater than DDGS. Protein retained for the DDGS, SBM50, and SBM100 treatments were 189.2, 193.4, and 193.2 g/d, respectively.

Carcass traits and Liver Outcomes

Carcass traits and liver outcomes are located in Table 3.4. Feeding SBM in replacement of DDGS resulted in linearly decreased DP ($P = 0.03$), but a linear increase in REA ($P = 0.02$). No effects were observed in HCW, RF, or marbling score ($P \geq 0.22$) with substitution of DDGS with SBM. Feeding SBM as a replacement of DDGS altered the distribution of liver scores ($P = 0.05$).Steers from SBM100 had fewer livers classified as normal and a greater proportion of livers classified as severely (A+ or greater) abscessed. The fewest severe abscesses and greatest proportion of normal livers were observed in the SBM50 treatment. The distribution of USDA Yield and Quality grades were not influenced by feeding SBM as a replacement of DDGS ($P \geq 0.36$).

Sera-Urea Nitrogen

Sera urea-N values are located in Figure 3.1. No treatment × day interaction was observed for SUN ($P = 0.20$). However, SUN values were affected by day ($P < 0.01$) and treatment ($P < 0.01$). Throughout the duration of the trial the SBM100 treatment

maintained greatest sera urea-N concentrations, the SBM50 treatment being intermediate, and the DDGS treatment had least concentrations of sera urea-N ($P < 0.01$). Further, sera urea-N concentrations increased overtime from d 77 to d 139 ($P < 0.01$).

DISCUSSION

Growth Performance

In the current study, dietary treatments differed in both CP and RDP concentrations. The three dietary treatments included DDGS (15.4% CP, 8% RDP), SBM50 (16.4% CP, 9% RDP), and SBM100 (17.4% CP, 10% RDP). Differing CP concentrations resulted from increased CP content of SBM compared to DDGS (52.85 and 30.79% CP, respectively; NASEM, 2016), and substitution of DDGS with SBM on a DM basis rather than ingredient basis. Soybean meal is an excellent source of CP and RDP (Devant et al., 2001), whereas DDGS contains a greater amount of RUP and NDF than SBM because of fractionation techniques of ethanol plants (Fontaine et al., 2007; Klopfenstein et al., 2008). Steers fed SBM in replacement or as a proportion of DDGS exhibited greater live FBW, ADG, and G:F, yet did not differ in DMI.

Theoretically, an increase in dietary CP and therefore urinary N excretion is subject to increased maintenance energy requirements of the animal because of greater hepatic energy demands. Jennings et al. (2018) reported cattle fed diets with 19.5% CP and high in rumen undegradable protein increased maintenance requirements 4 to 6% compared to cattle fed a 13.8% CP diet. Despite increased maintenance requirements, Hales et al. (2016) observed greater feed efficiency in cattle fed higher CP. They compared protein levels of 13.5 and 17.5% on finishing cattle performance using wet

distillers grains and supplemental soybean meal. Increasing CP and RDP in the finishing diet decreased DMI with no difference in ADG, resulting in improved G:F. Gleghorn et al. (2004), compared both levels of and source of CP using urea and cottonseed meal in steam-flaked corn-based diets. Steam-flaked corn-based diets were arranged in a 3 × 3 factorial with CP concentrations of 11.5, 13, or 14.5% of DM, and cottonseed meal replacing either 50 or 100% of urea. They reported no effects of protein source or concentration on DMI but did observe a tendency for a quadratic effect of CP concentration with the greatest ADG observed at 13% CP. Greater performance results were observed in cattle supplemented with greater amounts of RDP rather than just increasing concentrations of CP.

Understanding and using proper concentrations and ratios of rumen degradable protein to rumen undegradable protein may improve growth performance in finishing beef steers (Wagner et al., 2010). Microbial protein contribution to metabolizable protein supply is a dynamic function of both RDP and carbohydrate source. Cooper et al. (2002) completed three consecutive studies analysing the rumen degradable protein requirement supplied by urea on performance of finishing beef cattle. Steers were fed high-moisture corn-based diets in trial one and steam-flaked corn-based diets in trial two. Trial three used dry-rolled, high-moisture, and steam-flaked corn-based diets supplemented with different levels of urea which were decided based upon previous studies. They concluded that the requirement for rumen degradable protein differed depending upon corn processing methods. Cattle fed dry-rolled corn-based diets had the lowest requirement for RDP at 6.3% of DM, which agreed with results from Shain et al. (1998) and Milton et al. (1997) who observed limited effects of supplemented urea on performance of cattle fed

dry-rolled corn-based diets. Increased RDP requirements were observed in cattle fed high-moisture corn-based diets with improved feed efficiency observed in cattle fed 10 and 10.2% dietary RDP with the average across trials being 10.1% dietary RDP (Cooper et al., 2002).

More variable responses were observed across studies using steam-flaked corn-based diets. In trial two, maximal feed efficiency was observed in cattle fed 7.1% dietary RDP, whereas in trial three greatest feed efficiency was observed in cattle fed 9.5% dietary RDP (Cooper et al., 2002). These results were similar to observations by Wagner et al. (2010) who determined that cattle fed steam-flaked corn required greater than 7.4% dietary RDP, but speculated this requirement would not exceed 8.4%. As well, Gleghorn et al. (2004) reported the greatest ADG and feed efficiency in cattle fed steam-flaked corn-based diets with 8.2% dietary RDP.

The current study utilized high-moisture corn and high-moisture ear corn as the primary grain sources. Live growth performance responses align closely with results from Cooper et al. (2002). Linear increases were observed in live final BW and ADG as dietary RDP increased from 8 to 10% RDP. Similar to Gleghorn et al. (2004), no effects of protein source or concentration was detected on DMI. Thus, increased soybean meal and greater RDP resulted in improved G:F in the SBM treatments on a live basis and a tendency for greater G:F in the SBM50 treatment on a carcass adjusted basis. Further addition of RDP from SBM when increasing from partial to complete replacement of DDGS did not have appreciable outcomes on feed efficiency, likely resulting from increased metabolic energy needs with increasing CP concentration as described by Jennings et al., 2018.

Carcass Characteristics

Feeding SBM in replacement of DDGS resulted in increased ribeye area in the current experiment. Many reports indicate REA is not affected by protein source, concentration, or degradability (Walker et al., 2006; Wagner et al., 2010; Hales et al., 2016; Samuelson et al., 2023). Perkins et al., (1992) suggested that the variations in REA can be explained by final BW. Our observations of greater final BW in cattle fed SBM may better explain observations of greater REA in these treatments than protein source or concentration. In this experiment, the ratios of square cm of REA per kg of live final BW were 0.145, 0.146, and 0.147, for DDGS, SBM50, and SBM100, respectively.

In the current study, feeding SBM in replacement of DDGS, and thus increased CP and RDP, resulted in decreased DP. Samuelson et al. (2023) fed cattle diets containing 20% CP, one high in RUP and another high in RDP, compared to a standard diet containing 14% CP. Cattle fed high levels of RDP had greater DP and tended to have heavier HCW than steers fed high RUP. Observations of increased DP with higher dietary RDP is consistent with reports by Gleghorn et al. (2004) who observed linear increases in DP with increasing dietary RDP. However, Hales et al. (2016), reported no differences in DP between cattle fed 13.5 and 17.5% dietary CP. When comparing diets differing in RUP and RDP concentrations, Wagner et al. (2010) did not find any differences in DP but observed a tendency for a linear increase in HCW with increasing RDP concentrations. Similarly, Walker et al. (2006) did not report any differences in DP between cattle fed SBM or urea. Furthermore, studies comparing SBM to DDGS reported

no differences in DP between treatments (Mateo et al., 2004; Heiderscheit and Hansen, 2020; Pittaluga et al., 2021).

Historical data from Lawrence (2022) show a 0.8 to 2.5% reduction in dressed carcass yield associated with minor and severe abscesses, respectively. In the current study, cattle fed SBM had a greater prevalence and severity of liver abscesses. Thus, our observations of decreased DP in SBM fed cattle may be related to observed liver outcomes.

Liver Outcomes

Feeding soybean meal as a complete replacement for DDGS in the current experiment increased the number of livers classified as severely abscessed, whereas a combination of feeding SBM and DDGS resulted in the lowest number of abscessed livers. Liver abscesses in feedlot cattle are caused by a multitude of environmental factors and bacteria flora (Amachawadi and Nagaraja, 2016). Cattle fed high grain diets are more susceptible to acidosis and ruminitis, allowing opportunistic flora to enter the blood and shed bacterial emboli into portal circulation (Nagaraja and Chengappa, 1998). The most identified bacterium as being a primary cause of liver abscesses has been reported to be *Fusobacterium necrophorum* (Scanlan and Hathock, 1983; Nagaraja and Chengappa, 1998; Tadepalli et al., 2009; Amachawadi and Nagaraja, 2016). Recently, Aguiar Veloso and Drouillard (2020) reported lysine may play a role in the proliferation and virulence of ruminal *F. necrophorum* as a form of energy source for the bacterium. Because of the Maillard reaction during the production process of DDGS, the formation of cross-linkages renders a portion of the lysine contained within the distillers co-product as

biologically unavailable to the animal (Teodorowicz et al., 2018). However, this is a different case for soybean meal. The lysine content of SBM is approximately 6.16% of CP whereas DDGS is approximately 2.81% of CP (NASEM, 2021). The ability of SBM to provide adequate energy in the form of lysine to *F. necrophorum* could explain the increased liver abscess prevalence and severity in calves fed SBM100.

Sera Urea-N

Adverse effects of intensive animal feeding on air and water pollution is a topic of concern in the United States. Nitrogen (N) excreted in feces and urine, volatilizes into the air as nitrous oxide, or can leach into groundwater and streams as nitrates which can be toxic to aquatic life in high concentrations (Reed et al., 2015). Increased sera urea-N is a predictor of the quantity of N lost to the environment (Paul et al., 1998) and is a function of CP content of the diet, and nitrogen solubility and degradability in the diet (Hammond, 1983). As cattle mature, protein requirements as a percentage of dietary DM decrease (Cole et al., 2006). Optimum sera urea-N values of finishing cattle are between 7 and 8 mg/dL (Hammond 1983) with SUN values above 9 to 12 mg/dL suggested to be indicative of protein wastage in the ruminant animal (Cole et al., 2003; 2006). However, these values are expected to vary depending on diet quality, use of growth promotants, and inclusion of dietary feed additives (Hammond, 1983). In the current study, all dietary treatments exceeded optimum sera urea-N concentrations. At d 139, steers had greatly increased values consistent with N wastage with SBM100 having concentrations double those suggested by Cole et al., (2003, 2006). The increased CP and RDP in the SBM treatments increased sera urea-N concentrations compared to DDGS throughout the

duration of the study. The greatest sera urea-N concentrations were observed in the SBM100 treatment and were maintained throughout the duration of the trial, SBM50 was intermediate, and DDGS fed cattle had the lowest concentrations. These data support the conclusion that any differences or tendencies in growth performance or feed efficiency were caused by alterations in RDP supply rather than dietary CP.

SUMMARY

The use of SBM as a partial or complete replacement of DDGS resulted in greater daily gain and gain efficiency compared to DDGS when measured on a live basis. The reduced growth response observed in steers fed DDGS may be related to inadequate RDP in a high-moisture corn-based diet. The SBM fed cattle diet had a greater prevalence and severity of liver abscesses, which may be linked to increased ruminal lysine supply with SBM compared to DDGS. Feeding SBM resulted in decreased DP and increased REA, with no other differences observed in carcass characteristics. This decrease in DP could be related to the liver outcomes observed in SBM treatments. Based on these observations, when using SBM in replacement of DDGS on a DM basis, not a CP basis, partial replacement of DDGS with SBM is most ideal based on the current study.

LITERATURE CITED

Aguiar Veloso, V. Drouillard, J. S. 2020. On the Potential Role of Dietary Lysine as a Contributing Factor in Development of Liver Abscesses in Cattle. Frontiers in Veterinary Science, **7**:576647. doi: 10.3389/fvets.2020.576647

Amachawadi, R. G., Nagaraja, T. G. 2016. Liver abscesses in cattle: A review of incidence in Holsteins and of bacteriology and vaccine approaches to control in feedlot cattle. Journal of Animal Science, **94**(4): 1620–1632. doi: 10.2527/jas.2015-0261

AOAC. 2012. Official methods of analysis. 19th ed. Assoc. Off. Anal. Chem., Arlington, VA.

AOAC. 2016. Official methods of analysis. 20th ed. Assoc. Off. Anal. Chem., Arlington, VA

Asem-Hiablie, S., Rotz, C. A., Stout, R., Stackhouse-Lawson, K. 2016. Management characteristics of beef cattle production in the Northern Plains and Midwest regions of the United States. The Professional Animal Scientist, **32**(6): 736–749. doi: 10.15232/pas.2016-01539

Cole, N. A., Defoor, P. J., Galyean, M. L., Duff, G. C., Gleghorn, J. F. 2006. Effects of phase-feeding of crude protein on performance, carcass characteristics, serum urea nitrogen concentrations, and manure nitrogen of finishing beef steers. Journal of Anim Science, **84**(12):3421-32. doi: 10.2527/jas.2006-150

Cole, N. A., Greene, L. W., McCollum, F. T., Montgomery, T., McBride, K. 2003. Influence of oscillating dietary crude protein concentration on performance, acid-base balance,

and nitrogen excretion of steers. Journal of Animal Science, **81**(11): 2660–2668. doi: 10.2527/2003.81112660x

Cooper, R. J., Milton, C. T., Klopfenstein, T. J., Jordon, D. J. 2002. Effect of corn processing on degradable intake protein requirement of finishing cattle. Journal of Animal Science, **80**(1): 242-247. doi: 10.2527/2002.801242x.

Devant, M., Ferret, A., Calsamiglia, S., Casals, R., Gasa, J. 2001. Effect of nitrogen source in high-concentrate, low-protein beef cattle diets on microbial fermentation studied in vivo and in vitro. Journal of Animal Science, **79**(7): 1944–1953. doi: 10.2527/2001.7971944x

Fawcett, J. K., and J. E. Scott. 1960. A rapid and precise method for the determination of urea. Journal of Clinical Pathology, **13**(2):156-159. doi: 10.1136/jcp.13.2.156

Fontaine, J., Zimmer, U., Moughan, P. J., Rutherfurd, S. M. 2007. Effect of heat damage in an autoclave on the reactive lysine contents of soy products and corn distillers dried grains with solubles. use of the results to check on lysine damage in common qualities of these ingredients. Journal of Agricultural and Food Chemistry, **55**(26): 10737-10743. doi: 10.1021/jf071747c

Gleghorn, J. F., Elam, N. A., Galyean, M. L., Duff, G. C., Cole, N. A., Rivera, J. D. 2004. Effects of crude protein concentration and degradability on performance, carcass characteristics, and serum urea nitrogen concentrations of finishing steers. Journal of Animal Science, **82**: 2705–2717. doi: 10.2527/2004.8292705x

Hales, K. E., Shackelford, S. D., Wells, J. E., King, D. A., Pyatt, N. A., Freetly, H. C., Wheeler, T. L. 2016. Effects of dietary protein concentration and ractopamine

hydrochloride on performance and carcass characteristics of finishing beef steers. Journal of Animal Science, **94**(5): 2097–2102. doi: 10.2527/jas.2015-0225

Hammond, A. C. 1983. The Use of blood urea nitrogen concentration as an indicator of protein status in cattle. The Bovine Practitioner, **18**: 114–118. doi: 10.21423/bovine-vol1983no18p114-118

Heiderscheit, K. J., Hansen, S. L. 2020. Effect of rumen-protected lysine on growth performance, carcass characteristics, and plasma amino acid profile in feedlot steers. Translational Animal Science, **4**(3), txaa128–txaa128. doi: 10.1093/tas/txaa128

Jennings, J. S., Meyer, B. E., Guiroy, P. J., Cole, N. A. 2018. Energy costs of feeding excess protein from corn-based by-products to finishing cattle. Journal of Animal Science, **96**(2): 653–669. doi: 10.1093/jas/sky021

Klopfenstein, T. J., Erickson, G. E., Bremer, V. R. 2008. BOARD-INVITED REVIEW: Use of distillers by-products in the beef cattle feeding industry. Journal of Animal Science, **86**(5):1223-1231. doi: 10.2527/jas.2007-0550

Lawrence, T. E. 2022. Effect of Liver Abscessation on Carcass Outcomes. The Veterinary Clinics of North America. Food Animal Practice, **38**(3), 361–365. doi: 10.1016/j.cvfa.2022.08.003

Mateo, K. S., Tjardes, K. E., Wright, C. L., Koger, T. J., Rops, B. D. 2004. Evaluation of Feeding Varying Levels of Wet Distillers Grains with Solubles as Compared to Dry Distillers Grains with Solubles to Finishing Steers. South Dakota Beef Report, 2004. Paper 4. http://openprairie.sdstate.edu/sd_beefreport_2004/4

Milton, C. T., Brandt Jr., R. T., Titgemeyer, E. C. 1997. Effects of dietary nitrogen source and concentration in high-grain diets on finishing steer performance and nutrient digestion. Journal of Animal Science, **75**(10): 2813–2823. doi: 10.2527/1997.75102813x

Mjoun, K., Kalscheur, K. F., Hippen, A. R., Schingoethe, D. J. 2010. Ruminal degradability and intestinal digestibility of protein and amino acids in soybean and corn distillers grains products. Journal of Dairy Science, **93**(9): 4144–4154. doi: 10.3168/jds.2009-2883

Nagaraja, T. G., Chengappa, M. M. 1998. Liver abscesses in feedlot cattle: A review. Journal of Animal Science, **76**(1): 287–298. doi: 10.2527/1998.761287x

NASEM (National Academies of Sciences, Engineering, and Medicine). 2016. Nutrient Requirements of Beef Cattle. Revised 8th Ed.. National Academy Press, Washington, DC. doi: 10.17226/19014

NASEM (National Academies of Sciences, Engineering, and Medicine). 2021. Nutrient Requirements of Dairy Cattle: Eighth Revised Edition. Washington, DC: The National Academies Press. doi: 10.17226/25806.

Owens, F. N., Zinn, R. 1988. Protein metabolism of ruminant animals. In: D.C. Church, editor, The Ruminant Animal: Digestive Physiology and Nutrition. Prentice Hall, Englewood Cliffs, NJ. p. 227 – 249.

Paul, J. W., Dinn, N. E., Kannangara, T., Fisher, L. J. 1998. Protein content in dairy cattle diets affects ammonia losses and fertilizer nitrogen value. Journal of Environmental Quality, **27**(3): 528–534. doi: 10.2134/jeq1998.00472425002700030008x

Perkins, T. L., Green, R. D., Hamlin, K. E. 1992. Evaluation of ultrasonic estimates of carcass fat thickness and longissimus muscle area in beef cattle. Journal of Animal Science, 70(4): 1002–1010. doi: 10.2527/1992.7041002x

Pittaluga, A. M., Clark, C., Relling, A. E. 2021. Effect of protein source and nonroughage NDF content in finishing diets of feedlot cattle fed free-choice hay on growth performance and carcass characteristics. Translational Animal Science. **5**(4): txab224–txab224. doi: 10.1093/tas/txab224

Preston, R. L. 2016. Feed Composition Table. BEEF Magazine [Online] Available: https://www.beefmagazine.com/sites/beefmagazine.com/files/2016-feedcomposition-tablesbeef-magazine.pdf [2023 Oct. 13]

Reed, K. F., Moraes, L. E., Casper, D. P., Kebreab, E. 2015. Predicting nitrogen excretion from cattle. Journal of Dairy Science, **98**(5): 3025-35. doi: 10.3168/jds.2014-8397.

Salami, S. A., Devant, M., Apajalahti, J., Holder, V., Salomaa, S., Keegan, J. D., Moran, C. A. 2021. Slow-Release Urea as a Sustainable Alternative to Soybean Meal in Ruminant Nutrition. Sustainability, **13**(5): 2464. doi:10.3390/su13052464

Samuelson, K. L., Hubbert, M. E., Galyean, M. L., Löest, C. A. 2016. Nutritional recommendations of feedlot consulting nutritionists: The 2015 New Mexico State and Texas Tech University survey. Journal of Animal Science, **94**(6), 2648–2663. doi: 10.2527/jas.2016-0282

Samuelson, K. L., Hubbert, M. E., Oosthuysen, E. R., Löest, C. A. 2023. Effects of dietary protein concentration and degradability on performance, carcass characteristics, net energy utilization, and metabolizable protein balance of finishing beef heifers

receiving 0 or 400 mg of ractopamine hydrochloride. Applied Animal Science, **39**(2), 56–68. doi: 10.15232/aas.2022-02351

Scanlan, C. M., Hathock, T. L. 1983. Bovine rumenitis-liver abscess complex: A bacteriological review. The Cornell Veterinarian, **73**(3): 288–297.

Shain, D. H., Stock, R. A., Klopfenstein, T. J., Herold, D. W. 1998. Effect of degradable intake protein level on finishing cattle performance and ruminal metabolism. Journal of Animal Science, **76**(1): 242–248. doi: 10.2527/1998.761242x

Tadepalli, S., Narayanan, S. K., Stewart, G. C., Chengappa, M. M., Nagaraja, T. G. 2009. Fusobacterium necrophorum: A ruminal bacterium that invades liver to cause abscesses in cattle. Anaerobe, **15**(1): 36–43. doi: 10.1016/j.anaerobe.2008.05.005

Teodorowicz, M., Heniks, W. H., Wichers, H. J., Savelkoul, H. F. J., Voeding, L. S. 2018. Immunomodulation by Processed Animal Feed: The Role of Maillard Reaction Products and Advanced Glycation End-Products (AGEs). Frontiers in Immunology, **9**: 2088–2088. doi: 10.3389/fimmu.2018.02088

Wagner, J. J., Engle, T. E., Bryant, T. C. 2010. effect of rumen degradable and rumen undegradable intake protein on feedlot performance and carcass merit in heavy yearling steers. Journal of Animal Science, **88**(3): 1073–1081. doi: 10.2527/jas.2009-2111

Walker, D. K., Titgemeyer, E. C., Drouillard, J. S., Loe, E. R., Depenbusch, B. E., Webb, A. S. 2006. Effects of ractopamine and protein source on growth performance and carcass characteristics of feedlot heifers. Journal of Animal Science, **84**(10), 2795–2800. doi: 10.2527/jas.2005-614

Zinn, R. A., Barreras, A., Owens, F. N., Plascencia, A. 2008. Performance by feedlot steers and heifers: Daily gain, mature body weight, dry matter intake, and dietary energetics. Journal of Animal Science, **86**(10):2680-2689. doi: 10.2527/jas.2007-0561.

Zinn, R. A., Shen, Y. 1998. An evaluation of ruminally degradable intake protein and metabolizable amino acid requirements of feedlot calves. Journal of Animal Science, **76**(5):1280-1289. doi: 10.2527/1998.7651280x

TABLES

Table 3.1. Diet Composition[a]

	Treatment[b]											
	d 1 to 16			d 17 to 21			d 22 to 103			d 104 to 139		
Item[c]	DDGS	SBM50	SBM100	DDGS	SBM50	SBM100	DDGS	SBM50	SBM100	DDGS	SBM50	SBM100
Ingredient Composition, %												
HMEC	65.40	65.51	65.61	74.90	74.88	74.85	14.47	14.48	14.49	13.93	13.95	13.97
LS 1[d]	4.96	2.48	0.00	5.08	2.54	0.00	4.80	2.40	0.00	4.80	2.40	0.00
LS 2[e]	0.00	2.48	4.97	0.00	2.54	5.07	0.00	2.40	4.81	0.00	2.40	4.81
SBM	0.00	9.77	19.57	0.00	10.04	20.08	0.00	9.55	19.12	0.00	9.64	19.31
DDGS	19.82	9.93	0.00	20.02	10.00	0.00	19.25	9.63	0.00	19.54	9.78	0.00
DRC	0.00	0.00	0.00	0.00	0.00	0.00	16.31	16.32	16.34	55.95	56.03	56.11
HMC	0.00	0.00	0.00	0.00	0.00	0.00	39.28	39.31	39.34	0.00	0.00	0.00
GH	9.81	9.83	9.85	0.00	0.00	0.00	5.88	5.89	5.89	5.79	5.79	5.80
Nutrient Composition[f]												
DM, %	74.52	74.40	74.28	71.01	71.04	71.07	79.90	79.83	79.77	84.35	84.23	84.11
CP, %	15.08	16.08	17.07	15.16	16.22	17.28	15.45	16.48	17.51	15.37	16.36	17.35
RDP, %	8.34	9.37	10.41	8.11	9.35	10.47	8.00	9.03	10.06	7.96	9.00	10.05
NDF, %	25.24	22.81	20.38	20.53	18.06	15.58	19.72	17.29	14.86	17.73	15.36	12.99
ADF, %	12.94	11.96	10.98	10.01	9.01	8.02	8.71	8.01	7.31	7.33	6.73	6.12
Ash, %	5.98	6.16	6.34	5.33	5.52	5.70	5.68	5.82	5.97	5.50	5.63	5.77
EE, %	4.15	3.57	2.98	4.22	3.63	3.04	3.77	3.22	2.68	3.82	3.25	2.69
NEm, Mcal/kg[g]	1.97	1.90	1.89	1.97	1.96	1.96	2.07	2.06	2.06	2.06	2.05	2.04
NEg, Mcal/kg[h]	1.26	1.25	1.24	1.34	1.33	1.32	1.40	1.39	1.38	1.38	1.37	1.36

[a] All values except dry matter are on a DM basis

[b] DDGS = 100% DDGS; SBM50 = 50 % DDGS, 50% SBM; SBM100 = 100% SBM

[c] HMEC = high moisture ear corn; LS = molasses-based liquid supplement; SBM = soybean meal; DDGS = dried distillers grains plus solubles; DRC = dry rolled corn; HMC = high-moisture corn; GH = grass hay; DM = dry matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; EE = ether extract; NEm = net energy for maintenance; NEg = net energy for gain.

[d] Liquid supplement 1 contained (DM basis): 44.46% CP, 38.78% non-protein nitrogen, 0.904 Mcal/kg of NEm, 0.573 Mcal/kg of NEg, 0.90% ether extract, 16.52% total sugars, 50.77% ash, 11.00% calcium, 0.38% P, 7.07% K, 0.13% Mg, 6.00% NaCl, 3.54% Na, 0.41% S, 4.30 ppm Co, 200.00 ppm Cu, 12.11 ppm I,

2.81 mg/kg EDDI, 525.35 ppm Fe, 404.93 ppm Mn, 2.93 ppm Se, 1,800 ppm Zn, 9,160.35 IU/kg Vitamin A, 91.60 IU/kg Vitamin E, and 585.37 g/ton monensin sodium.

[e] Liquid supplement 2 contained (DM basis): 7.32% CP, 1.03% non-protein nitrogen, 1.190 Mcal/kg of NEm, 0.772 Mcal/kg of NEg, 1.36% ether extract, 27.18% total sugars, 50.77% ash, 11.00% calcium, 0.38% P, 7.07% K, 0.12% Mg, 6.00% NaCl, 2.94% Na, 0.46% S, 4.38 ppm Co, 200.00 ppm Cu, 12.11 ppm I, 2.81 mg/kg EDDI, 436.14 ppm Fe, 409.87 ppm Mn, 2.93 ppm Se, 1,800 ppm Zn, 9,160.35 IU/kg Vitamin A, 91.60 IU/kg Vitamin E, and 585.37 g/ton monensin sodium

[f] Tabular NE from Preston (2016) and actual nutrient compositions

[g] Net energy for maintenance

[h] Net energy for gain

Table 3.2. Dietary amino acid content[a].

	Treatment [b]											
	d 1 to 16			d 17 to 21			d 22 to 103			d 104 to 139		
Item, g/d	DDGS	SBM50	SBM100	DDGS	SBM50	SBM100	DDGS	SBM50	SBM100	DDGS	SBM50	SBM100
Arg	46.15	70.08	95.59	49.35	74.06	100.42	58.43	84.10	110.03	61.74	89.29	116.35
His	30.17	35.46	41.48	32.38	37.89	44.19	36.23	41.83	47.64	38.26	44.38	50.32
Ise	40.18	52.11	65.16	43.04	55.40	68.96	46.35	59.11	72.11	48.96	62.73	76.19
Leu	138.52	141.61	147.44	149.11	152.61	159.17	157.07	159.91	163.77	165.79	169.53	172.77
Lys	31.07	53.80	77.79	33.29	56.73	81.45	37.85	62.30	86.89	39.98	66.15	91.90
Met	21.55	22.52	23.93	23.07	24.12	25.66	25.98	26.93	28.06	27.44	28.58	29.62
Phe	55.62	66.30	78.36	59.73	70.84	83.44	64.32	75.67	87.39	67.92	80.28	92.30
Thr	41.19	49.87	59.60	44.13	53.16	63.31	48.34	57.58	67.09	51.06	61.10	70.87
Trp	4.83	9.42	14.24	4.88	9.63	14.61	9.23	14.15	19.11	9.80	15.07	20.25
Val	52.58	61.91	72.51	56.25	65.98	77.08	62.24	72.12	82.36	65.75	76.53	87.01

[a] Calculated from NASEM, 2021

[b] DDGS = 100% DDGS; SBM50 = 50 % DDGS, 50% SBM; SBM100 = 100% SBM

Table 3.3. Influence of substituting soybean meal for dried distillers on growth performance responses of finishing beef steers.

	Treatment[a]				*P*-values		
Item	DDGS	SBM50	SBM100	SEM[d]	F-test	Linear	Quadratic
Pens, n	63	61	63				
Steers, n	8	8	8				
Initial BW[b], kg	382	383	383	1.0	0.84	0.57	0.91
d 1 to d 35							
BW d35[b], kg	446	450	457	1.3	0.01	0.01	0.33
ADG, kg	1.82	1.91	2.10	0.036	0.01	0.01	0.35
DMI, kg	9.90	9.84	9.97	0.059	0.31	0.39	0.21
G:F	0.185	0.196	0.211	0.0033	0.01	0.01	0.61
F:G[c]	5.41	5.10	4.74	-	-	-	-
d 36 to d 77							
BW d77[b], kg	541	543	547	1.9	0.08	0.03	0.81
ADG, kg	2.25	2.22	2.15	0.044	0.33	0.16	0.63
DMI, kg	10.99	10.78	10.62	0.109	0.08	0.03	0.85
G:F	0.205	0.207	0.204	0.0032	0.77	0.69	0.55
F:G[c]	4.88	4.83	4.90	-	-	-	-
d 78 to d 105							
BW d105[b], kg	579	582	584	1.9	0.19	0.07	0.98
ADG, kg	1.36	1.36	1.32	0.041	0.66	0.43	0.67
DMI, kg	11.00	10.92	10.91	0.133	0.88	0.65	0.83
G:F	0.124	0.125	0.121	0.0038	0.71	0.58	0.55
F:G[c]	8.06	8.00	8.26	-	-	-	-
d 106 to d 139							
BW d139[b], kg	621	631	631	3.0	0.04	0.03	0.14
ADG, kg	1.22	1.47	1.38	0.075	0.10	0.18	0.09
DMI, kg	11.56	11.51	11.42	0.101	0.60	0.33	0.87
G:F	0.106	0.128	0.120	0.0059	0.05	0.10	0.06
F:G[c]	9.43	7.81	8.33	-	-	-	-
Cumulative (live-basis)							
ADG, kg	1.71	1.79	1.78	0.023	0.06	0.05	0.15
DMI, kg	10.86	10.75	10.71	0.075	0.38	0.18	0.72
G:F	0.158	0.167	0.167	0.0173	0.01	0.01	0.05
F:G[c]	6.33	5.99	5.99	-	-	-	-
Cumulative (HCW/0.625)							
Final BW, kg	641	648	644	3.0	0.32	0.60	0.16
ADG, kg	1.86	1.91	1.87	0.024	0.42	0.77	0.21
G:F	0.172	0.178	0.175	0.0020	0.14	0.26	0.10
F:G[c]	5.81	5.62	5.71	-	-	-	-

Applied Energetics[e]							
NEm[f], Mcal/kg	2.01	2.10	2.10	0.016	0.01	0.01	0.03
NEg[g], Mcal/kg	1.35	1.43	1.43	0.014	0.01	0.01	0.03
O/E[h] NEm	0.98	1.03	1.03	0.008	0.01	0.01	0.03
O/E[h] NEg	0.99	1.04	1.04	0.011	0.01	0.01	0.04
Retained protein, g/d	189.2	193.4	193.2	-	-	-	-

[a] DDGS = 100% DDGS; SBM50 = 50 % DDGS, 50% SBM; SBM100 = 100% SBM
[b] A 4% pencil shrink was applied to BW measures to account for gastrointestinal tract fill.
[c] Calculated as; 1/G:F
[d] Pooled standard error of the mean (SEM)
[e] Calculated from live BW shrunk 4%
[f] Net energy for maintenance
[g] Net energy for gain
[h] Observed to Expected

Table 3.4. Effect of substituting soybean meal for dried distillers on steer carcass and quality characteristics.

	Treatment[a]				*P*-values		
Item[b]	DDGS	SBM50	SBM100	SEM[c]	F-test	Linear	Quadratic
Carcass Traits							
HCW, kg	401	405	402	1.9	0.32	0.60	0.16
DP[d], %	64.60	64.10	63.75	0.251	0.09	0.03	0.80
REA, cm^2	90.13	92.19	93.03	0.774	0.05	0.02	0.54
RF, cm	1.40	1.50	1.45	0.046	0.22	0.28	0.17
Marbling[e]	519	531	524	14.9	0.85	0.83	0.60
Yield Grade	3.25	3.30	3.19	0.078	0.63	0.60	0.42
RY, %	49.55	49.47	49.69	0.161	0.61	0.55	0.44
EBF[f], %	31.02	31.61	31.23	0.349	0.49	0.68	0.27
AFBW[f], kg	580	577	579	5.4	0.91	0.87	0.69
Quality Grade Distribution, %							
Select	6.3	5.0	6.5	-	0.92		
Low Choice	39.7	40.7	38.7				
Average Choice	33.3	30.5	33.9				
High Choice	17.5	17.0	16.1				
Prime	3.2	6.8	4.8				
Yield Grade Distribution, %							
1	0.0	3.3	3.2	-	0.36		
2	41.2	30.1	46.0				
3	55.6	63.3	44.4				
4	3.2	3.3	4.8				
5	0.0	0.0	1.6				
Liver Abscess Prevalence, %							
Normal	74.6	81.7	63.5	-	0.05		
A-	4.8	8.3	9.5				
A	3.2	5.0	0.0				
A+	17.4	5.0	27.0				

[a] DDGS = 100% DDGS; SBM50 = 50 % DDGS, 50% SBM; SBM100 = 100% SBM

[b] HCW = hot carcass weight; DP = dressing percent; REA = ribeye area; RF = rib fat; RY = retail yield; EBF = empty body fat; AFBW = adjusted final body weight

[c] Pooled standard error of the mean (SEM)

[d] Calculated as: (HCW/Final BW shrunk 4%) × 100.

[e] $Small^{00}$ = 400

[f] Calculated according to Guiroy et al. (2002).

FIGURES

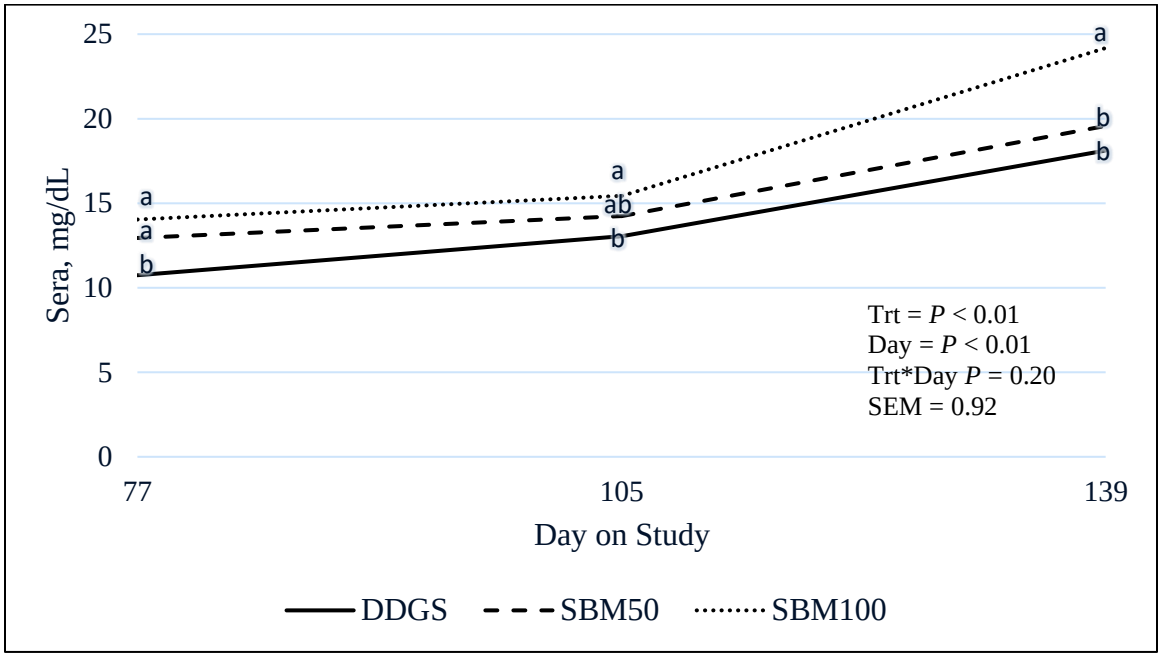

Figure 3.1. Interaction for calculated sera urea-N between cattle fed soybean meal in partial or complete replacement of dried distillers grains plus solubles. Dried distillers grains plus solubles were included in the diet at 20% diet DM (DDGS), soybean meal replaced 50% DM of the DDGS in the diet (SBM50), or soybean meal replaced 100% DM of the DDGS in the diet (SBM100) in a randomized complete block design. For each of the three treatments there were 63 steers housed in eight pen replicates. Two steers per pen closest to mean pen d 35 BW were chosen for sample collection. Sera urea-N measures were analysed as repeated measures. Means with different superscripts differ ($P < 0.05$).