University of Nebraska - Lincoln Digital Commons@University of Nebraska - Lincoln

Theses and Dissertations in Animal Science

Animal Science Department

4-19-2012

Nutrient mass balance and performance of feedlot cattle fed barley based diets in large pens in western Canada

Erin M. Hussey University of Nebraska-Lincoln, erinmhussey@gmail.com

Follow this and additional works at: http://digitalcommons.unl.edu/animalscidiss



Part of the Animal Sciences Commons

Hussey, Erin M., "Nutrient mass balance and performance of feedlot cattle fed barley based diets in large pens in western Canada" (2012). Theses and Dissertations in Animal Science. Paper 49. http://digitalcommons.unl.edu/animalscidiss/49

This Article is brought to you for free and open access by the Animal Science Department at DigitalCommons@University of Nebraska - Lincoln. It has been accepted for inclusion in Theses and Dissertations in Animal Science by an authorized administrator of DigitalCommons@University of Nebraska - Lincoln.

Nutrient mass balance and performance of feedlot cattle fed barley based diets in large pens in western Canada

by

Erin M. Hussey

A THESIS

Presented to the Faculty of

The Graduate College at the University of Nebraska

Partial Fulfillment of Requirements

For the Degree of Master of Science

Major: Animal Science

Under the Supervision of Professor Galen E. Erickson

Lincoln, Nebraska

May, 2012

Nutrient mass balance and performance of feedlot cattle fed barley based diets in large pens in western Canada

Erin M. Hussey, MS.

University of Nebraska, 2012

Advisor: Galen E. Erickson

Three separate large pen commercial feeding trials with approximately 9,000 heifers with either eight or ten reps/treatment were conducted at a Western Feedlots Ltd.-High River, a commercial feedyard near High River, AB, Canada. For all three experiments, Near Infrared Spectroscopy (NIRS) was used to segregate feed barley. In Exp. 1, barley was segregated based on digestible energy (DE) content as predicted by NIRS and heifers were fed low or high DE barley, or a 50:50 blend of the two. Feeding low DE barley improved weight gain, dry matter intake (DMI), and mortality; with little effect on carcass composition compared to high DE barley. In Exp. 2, barley was segregated based on starch:neurtal detergent fiber (NDF) ratio. Barley starch:NDF greater than 3.25 was considered high starch: NDF, and less than 3.25 was considered low starch:NDF. In this experiment, main effects of high and low starch:NDF barley and inclusion of 0 or 20% corn-based DDGS were evaluated. Feeding low starch: NDF barley improved feedlot performance, increased dry matter (DM) removed from the pen, and slightly increased N loss due to an increase in N intake. Feeding 20 % DDGS increased DMI, had a slight negative impact on G:F, and increased N and P losses due to increased

intake and no change in manure nutrients. In Exp. 3, barley was segregated based on starch:NDF ratio similar to Exp. 2. Main effects of high and low starch:NDF barley and inclusion of 25 or 48 mg/kg monensin were evaluated. Feeding LOW starch:NDF barley and 25RUM improved feedlot performance and carcass characteristics, with minimal effects on manure nutrients and nutrient losses.

ACKNOWLEDGEMENTS

A great deal of gratitude is extended to Feedlot Health Management Services Ltd. and Western Feedlots Ltd. for providing the financial support which made this project possible. Appreciation is also expressed to the management and staff at Western Feedlots Ltd. of High River, AB for providing cattle and facilities for all of the feedlot trials.

I would like to extend sincere appreciation to G.E. Erickson, R.E. Peterson, D.D. Schulte, and T.J. Klopfenstein for sitting on the Committee and guiding this program to completion. In addition, a huge thank you to L.O. Burciaga-Robles and M.L. May for providing invaluable support.

Finally, I wish to thank my parents, Byron and Pat Hussey, sister Kiersten

Hussey, and a long list of friends for their constant support and overwhelming

encouragement. Once again, I am reminded of, and humbled by, just how lucky I am. I

will always hold these experiences close.

TABLE OF CONTENTS

Introduction	 .	1
CHAPTER I: A REVIEW OF THE LITERATURE		3
Barley	• • • • • • • • • • • • • • • • • • • •	3
General Information on Barley Grain	3	
Barley Processing for Inclusion in Finishing Diets		
Digestible Energy and Starch Content of Barley		
Acidosis		
Dried Distillers Grains Plus Solubes	• • • • • • • • • • • • • • • • • • • •	11
Production of Distillers Grains	11	
Nutrient Composition of Distillers Grains	12	
Effect of Dried Distillers Grains on Finishing Cattle Performance		
Economic Factors Associated with Feeding Distillers Grains	15	
Monensin	•••••	16
General Information on Monensin	16	
Monensin and Feedlot Performance	18	
Monensin Level and Feedlot Performance	19	
Monensin, Grain Source and Forage Level	22	
Monensin and Acidosis	24	
Nutrient Mass Balance	•••••	25
General Information on Manure as a Fertilizer	25	
Methods to Reduce N Losses from the Feedlot	26	
Distillers Grains and Nutrient Mass Balance	30	
Summary	• • • • • • • • • •	33
Objectives	• • • • • • • • • • • • • • • • • • • •	35
References		
CHAPTER II: EVALUATION OF THE EFFECTS OF FEEDING HIGH AND LOW	' ENEF	RGY
BARLEY ON FEEDLOT CATTLE PERFORMANCE IN WESTERN CANADA		
Abstract		45
Introduction		46
Materials and Methods		47
Study Facilities	47	
Barley Attributes	48	
Study Animals	49	
Experimental Design	50	
Animal Health and Marketing	52	
Statistical Analysis	53	

Results and Discussion	54
Barley Attributes	54
Feedlot Performance	54
Carcass Characteristics	56
Animal Health	57
Conclusions	58
References	59
Table 1. Definitions and calculations for cattle production lot variables from a stuthe effects of feeding high and low energy barley on feedlot cattle performance in Canada	western62
Table 2. Diet composition and chemical analyses of the total mixed rations fed in evaluating the effects of feeding high and low energy barley on feedlot cattle per western Canada	formance in
Table 3. Barley descriptive data measured by Near Infrared Spectroscopy (NIRS evaluating the effects of feeding high and low energy barley on feedlot cattle perfects of the control of th	formance in
Table 4. Feedlot performance data summary from a study evaluating the effects and low energy barley on feedlot cattle performance in western Canada	0 0
Table 5. USDA Yield Grade and Quality Grade distribution summary from a stuthe effects of feeding high and low energy barley on feedlot cattle performance in Canada	western
Table 6. Morbidity and mortality data summary from a study evaluating the effective high and low energy barley on feedlot cattle performance in western Canada	
CHAPTER III: NUTRIENT MASS BALANCE AND PERFORMANCE OF FEI CATTLE FED BARLEY BASED DIETS WITH AND WITHOUT DISTILLER: PLUS SOLUBLES	S GRAINS
Abstract	68
Introduction	69
Materials and Methods	70
Study Facilities	71
Study Animals	71
Experimental Design	71
Animal Health and Marketing	74
Nutrient Balance	76
Statistical Analysis	77
Results and Discussion	77
Feedlot Performance and Carcass Characteristics	78
Animal Health	82
Nutrient Balance	82
Conclusions	88
References	89

Table 1. Definitions and calculations for cattle production lot variables from a study evaluating the effects of feeding high and low energy barley on feedlot cattle performance in western Canada
Table 2. Diet composition and chemical analyses of the total mixed rations fed in a study evaluating the effects of feeding high and low starch:NDF barley and 0 or 20% DDGS on feedlot cattle performance in western Canada
Table 3. Growth performance and carcass characteristic data summary from a study evaluating the effects of feeding high and low starch: NDF barley and 0 or 20% DDGS on feedlot cattle performance in western Canada
Table 4. Yield and quality grade data summary from a study evaluating the effects of feeding high and low starch:NDF barley and 0 or 20% DDGS on feedlot cattle performance in western Canada
Table 5. Morbidity and mortality data summary from a study evaluating the effects of feeding high and low starch:NDF barley and 0 or 20% DDGS on feedlot cattle performance in western Canada
Table 6. Chemical analyses of manure samples from a study evaluating the effects of feeding high and low starch:NDF barley and 0 or 20% DDGS on feedlot cattle performance in western Canada
Table 7. Nitrogen mass balance from a study evaluating the effects of feeding high and low starch:NDF barley and 0 or 20% DDGS on feedlot cattle performance in western Canada99
Table 8. Phosphorus mass balance from a study evaluating the effects of feeding high and low starch:NDF barley and 0 or 20% DDGS on feedlot cattle performance in western Canada 100
Figure 1. Distribution of starch:NDF measured by Near Infrared Spectroscopy (NIRS) in a study evaluating the effects of feeding high and low starch:NDF barley and 0 or 20% DDGS on feedlot cattle performance in western Canada
CHAPTER IV: NUTRIENT MASS BALANCE AND FEEDLOT PERFORMANCE OF FEEDLOT CATTLE FED BARLEY BASED DIETS WITH DIFFERENT LEVELS OF MONENSIN
Abstract
Introduction
Materials and Methods 104
Study Facilities
Study Animals
Experimental Design
Animal Health and Marketing
Nutrient Balance
Statistical Analysis
Results and Discussion
Feedlot Performance
Carcass Characteristics
Animal Health117
Nutrient Balance
Conclusions 121
Deferences 122

Table 1. Definitions and calculations for cattle production lot variables from a study evaluating the effects of feeding high and low energy barley on feedlot cattle performance in western Canada
Table 2. Diet composition and chemical analyses of the total mixed rations fed in a study evaluating the effects of feeding high and low starch: NDF barley and 25 or 48 mg/kg monensin on feedlot cattle performance in western Canada
Table 3. Growth performance and carcass characteristic data summary from a study evaluating the effects of feeding high and low starch: NDF barley and 25 or 48 mg/kg monensin on feedlot cattle performance in western Canada
Table 4. Yield and quality grade data summary from a study evaluating the effects of feeding high and low starch:NDF barley and 25 or 48 mg/kg monensin on feedlot cattle performance in western Canada
Table 5. Morbidity and mortality data summary for a study evaluating the effects of feeding high and low starch:NDF barley and 25 or 48 mg/kg monensin on feedlot cattle performance in western Canada
Table 6. Chemical analyses of manure samples from a study evaluating the effects of feeding high and low starch:NDF barley and 25 or 48 mg/kg monensin on feedlot cattle performance in western Canada
Table 7. Nitrogen mass balance summary from a study evaluating the effects of feeding high and low starch:NDF barley and 25 or 48 mg/kg monensin on feedlot cattle performance in western Canada
Table 8. Phosphorus mass balance summary from a study evaluating the effects of feeding high and low starch:NDF barley and 25 or 48 mg/kg monensin on feedlot cattle performance in western Canada
Figure 1. Distribution of starch:NDF of barley measured by near infrared spectroscopy (NIRS) in a study evaluating the effects of feeding high and low starch:NDF barley and 25 or 48 mg/kg monensin on feedlot cattle performance in western Canada

Introduction

Feed cost of gain accounts for 65-80% of the total cost of feedlot production. Therefore, understanding the nutrient profile of the feed consumed by animals in the feedlot is important to understand. At present, most feedlots procure grain based on physical attributes such as plumpness, bushel weight, and moisture. Plumpness is measured as the percentage of a sample rejected by a 0.24 cm screen. Bushel weight is measured as the weight of 0.5 L of grain in grams. Based on these physical characteristics, some feedlots have pricing mechanisms set in place for grain that does not meet site specifications. These pricing mechanisms may or may not correlate with the feeding value and animal performance observed in the feedlot. Near Infrared Spectroscopy (NIRS) can save considerable time and resources by testing all of the above mentioned outcomes simultaneously compared to the conventional method of submitting samples to a laboratory for wet chemistry and potentially allow for the segregation of grain based on parameters that affect animal performance.

Barley is a major cereal grain used for feeding cattle in Western Canada and the Pacific Northwest. In an effort to reduce shrink loss and decrease storage space requirements, many feedlots have chosen to reduce or even eliminate forage from finishing rations. By nature, diets without roughage create challenges with respect to feeding management. Rumen degradation of grains is much more rapid than breakdown of forages, especially barley grain because it lacks the protective coating of zein protein found in corn, and is 52-73% starch (Waldo 1973). If rumen degradation of starch occurs rapidly, rumen pH declines, and can lead to acidosis and acidosis-related disorders (i.e.

laminitis, liver abscesses, bloat). Such conditions ultimately decrease the intake and gain of feedlot cattle.

Ethanol production capacity has changed greatly in recent years and as ethanol production increased, dry distillers grains plus solubles (DDGS) production has increased as well (Stock et al., 2000). Expansion of the US ethanol industry has prompted a number of cattle producers in the US and Canada to incorporate distillers grains plus solubles (DGS) in feedlot rations as a protein or energy source (>20% diet DM) of dietary protein and energy for cattle DGS is (NRC, 1996; Klopfenstein et al., 2008). During the dry milling process, starch is removed and fermented to produce ethanol, resulting in a 3-fold increase of all other nutrients (Klopfenstein et al., 2008). Feeding DGS has been shown to improve ADG and G:F in corn (Klopfenstein et al., 2008) and barley (Walter et al., 2010) based diets with no deleterious effects on carcass quality.

When DGS are fed as an energy source (greater than 20% of diet DM), protein and phosphorus exceed NRC requirements due to the increase in nutrient content (Klopfenstein et al., 2008). Inclusion of distiller's grains therefore increases nutrients excreted in manure, which in turn impacts the fertilizer value of manure (Bremer et al., 2009). The excess nitrogen (N) and phosphorus (P) excreted can create environmental issues, as there is the potential to impact air and water quality. Phosphorus in the manure is not volatilized so most of the P excreted is in the manure and runoff (Klopfenstein and Erickson, 2002). Nitrogen, however, may be volatilized and lost from the pen surface as ammonia (Erickson and Klopfenstein, 2010). Some mass balance studies have been conducted evaluating the effects of distillers grains plus solubles on nutrient mass

balance, but no research has evaluated the effects of barley fed in combination with cornbased DDGS on nutrient mass balance.

Monensin (Rumensin[®], Elanco Animal Health, Indianapolis, Indiana) is an ionophore commonly fed to feedlot cattle to improve feed efficiency. Ionophores may enhance the efficiency of ruminal fermentation by shifting microbial profiles, stabilizing ruminal pH, and reducing feed intake variation. Ultimately, these mechanisms may also mitigate the increased risk of acidosis associated with feeding high-concentrate diets. Feeding barley with a high energy or starch content imposes a greater risk of digestive disturbances than feeding barley with a low energy or starch content, thus increasing dietary monensin concentration may be beneficial in barley based diets, and especially with high energy or high starch barley.

A review of the literature on feeding barley, DDGS, and monensin to feedlot cattle was conducted to better understand current research on feeding barley, DDGS, and monensin and their effects on feedlot performance, carcass characteristics, and nutrient mass balance.

CHAPTER I: A REVIEW OF THE LITERATURE

Barley

General Information on Barley Grain

Barley (*Hordeum vulgare* L.) is the fourth most universally grown crop (Nilan and Ullrich, 1993) largely because it is adaptable to a variety of growing environments and can thus be grown around the world. Barley is a short season, early maturing crop, classified by the physical arrangement of the kernels on the plant (two-rowed or six-

rowed), and grown in both irrigated and dryland system in Canada and the United States. In 2010, 6.984 million tons of barley were produced in western Canada where its' adaptability to temperate climates and short dry growing seasons provides advantages over other cereal grains. Of the 6.984 million tones, 4.559 million tons were produced in AB, 1.938 million tons were produced in Saskatchewan, and 478,000 tons were produced in Manitoba (Canadian Grain Commission, 2010).

High grain diets are common in beef cattle feedlots in Western Canada because of the large supply of feed quality grain. Barley has traditionally been the primary grain used in feedlot rations in western Canada and the Pacific Northwest as an energy and protein source. The nutrient content compares favorably with that of corn, oats, wheat, and milo (NRC, 1996). The crude protein (CP) content of barley is higher than corn and the energy content (TDN, NEm, NEg) of barley is slightly lower than corn due to a higher ADF and NDF content (NRC, 1996). Barley grain is characterized by 19-21% NDF and 52-73% starch (Waldo, 1973). However, nutrient composition is highly variable and may be affected by geographical location, growing conditions, year grown, two-row or six-row, feed or malting type, and season planted (Taylor, 1985; Kemalyan et al. 1990; and Miller 1992).

When 73 selected accessions grown in 1996 and 1997 were analyzed, six-row types had greater (P<0.01) DM, ADF, particle size, and lower (P<0.01) starch content, DM digestibility, and digestible starch content compared to two-row types (Bowman et al., 2001).

This inherent variability leads to differences in animal performance (Hinman 1979). McDonnell et al. (2004) conducted a study with 32 crossbreed beef heifers (initial weight 349 kg \pm 2.2 kg). Heifers were individually fed finishing diets for 84 d in a 2 x 2 factorial experiment examining the effects of barley cultivar (Harrington vs. Valier) and growing environment (irrigated vs dryland) on animal performance, carcass characteristics, and nutrient digestibility. No differences in ADG (P=0.46; average 1.78 kg/d) or final weight (P=0.23; average 498 kg) were detected due to cultivar. Cultivar did not affect DMI (P=0.80; average 9.8 kg/d), or feed efficiency (P=0.63; average 18.3 kg gain/100 kg of feed). Growing environment did not affect ADG (P = 0.17; average 1.77 kg/d), or final weight (P = 0.20; average 498 kg). Heifers fed diets containing irrigated barley had lower (P < 0.01) DMI than heifers fed diets containing dryland barley (9.3 vs. 10.3 kg/d, respectively). Feed efficiency was higher ($P \le 0.01$) for heifers fed diets containing irrigated barley than for those fed dryland barley (19.8 vs. 16.8 kg gain/100 kg of feed). Barley NEm (P=0.63; average 2.41 Mcal/kg) and NEg (P=0.56; average 1.64 Mcal/kg) were not affected by cultivar. Irrigated barley NEm and NEg (2.58 and 1.79 Mcal/kg, respectively) contents were higher (P<0.01) than dryland barley NEm and NEg (2.24 and 1.49 Mcal/kg, respectively). Cultivar, growing environment or their interaction did not affect (P>0.06) carcass characteristics. Dry matter digestibility was higher (P=0.02) for diets containing Valier than for diets containing Harrington (77.6 vs. 74.9 %, respectively). Starch digestibility was not affected (P=0.13) by cultivar. Growing environment did not affect (P>0.06) nutrient digestibility. The dryland growing environment increased barley ADF content 47% and decreased starch content 12%, resulting in lower NE relative to irrigated barley. The lower starch content of dryland

barley may have caused heifers to increase DMI to meet their energy requirements, thus making irrigated barley a more efficient feed source.

Barley grain, like other grains, is high in starch (52-73%, Waldo 1973), making it a concentrated energy source. The ease of transport, storage, and mixing of grains makes them more attractive than forages. Starch is fermented rapidly to produce various volatile fatty acids (VFA's), creating an abundance of available energy in the rumen. The low pH conditions in the rumen that result from rapid degradation of starch when high grain diets are fed are conducive to digestive disorders including acidosis, liver abscesses, laminitis, and bloat, each of which are known to negatively affect intake and ADG.

Barley Processing for Inclusion in Finishing Diets

Several studies have compared feeding whole barley versus processed barley. Barley grain has a fibrous hull, and is more resistant to mastication than corn (Beauchemin et al. 1994), so some form of processing is beneficial. Toland (1976) compared whole barley to dry-rolled barley, and found that total tract digestibility for whole barley was, on average, 52.5%, whereas the digestibility of dry-rolled barley averaged 85.2%. Thus, dry-rolling barley increases digestibility. Processing barley also contributes to improved feedlot performance. In a study comparing whole barley to dry-rolled barley, Mathison et al. (1991) observed a numerical increase in ADG (3.03 vs 2.86 lb/d) and an improvement in feed efficiency (F:G was 6.28 vs 7.25) when barley was dry-rolled.

Barley grain is often tempered and then rolled (temper-rolled). The grain is soaked in water, with or without a surfactant, for 12 to 24 hours to increase moisture

content to 18-22% before it is rolled to standardize moisture content and reduce wear on processing equipment. Temper-rolling barley improves ADG and but has variable effects on DMI and G:F. Hinman and Combs (1983) observed an increase in ADG and DMI with temper-rolling compared to dry-rolling, but did not observe a difference in G:F. In contrast, Combs and Hinman (1984) reported improvements in ADG and G:F when barley was temper-rolled versus dry-rolled, but no difference in DMI.

Barley may also be steam-rolled/steam-flaked. However, there does not appear to be an advantage to steam-rolling/steam-flaking over dry-rolling. Hinman and Combs (1984) noted no advantages in ADG, DMI, and G:F for steam-rolling over dry-rolling or temper-rolling, but marbling score was increased for steers fed steam-rolled barley. Similarly, Grimson et al. (1987) observed no differences in ADG or G:F when comparing dry-rolling to steam-flaking in finishing diets. Lastly, Engstrom et al. (1992) compared steam-flaked barley to dry-rolled barley, and observed no differences in ADG, G:F, or DMI. Zinn (1993) conducted a feedlot growth performance trial to determine the effects of barley processing method on the comparative feeding value of barley in 90% concentrate finishing diets. Cattle were fed steam-flaked corn (SFC), dry-rolled barley, steam-rolled barley, coarse-rolled barley, or thin-rolled barley. Average daily gain was similar, but DMI was lower for steam-rolled barley than for dry-rolled barley. Diet NE was greater for steam-rolled barley than for dry-rolled barley.

Wang et al. (2003) evaluated the effects of six different processing techniques for barley grain in a 3 by 2 factorial arrangement of grain conditions and roller settings on ruminal degradation of the gain. The three pre-rolling barley conditions were dry (D; non-tempered, 11% moisture), tempered to 20% moisture (M), and tempered to 20%

moisture with surfactant (MS). The two roller settings were RD and RMS. Setting RD produced visually optimal particle sizes from D barley, and yielded a volume weight of 516 g/L and a kernel thickness of 2.23 mm. Setting RMS, which was tighter than RD, produced visually optimal particle sizes from MS barley, and yielded a volume weight of 450 g/L and kernel thickness of 2.00mm. Steers fed the more highly-processed barley had lower DMI, slightly lower ADG, but increased G:F, and heavier carcasses compared to steers fed barley that was less extensively processed. Increasing the extent of processing may promote rapid rumen degradation of starch which often causes digestive disturbances, such as acidosis and bloat (Owens et al., 1997), and a reduction in feed efficiency. In addition, increasing extent of processing will result in additional energy costs. Thus, optimal processing method represents a balance between optimizing grain utilization by the animal and minimizing economic costs associated with processing.

Digestible Energy and Starch Content of Barley

Digestible energy (DE) is considered the single most important criterion of nutritional quality of feed grains (Canada Grains Council 1972) and may be affected by the fiber content of barley (Bhatty et al., 1975). Digestible energy is the energy in the feedstuff minus the energy lost in the feces and thus has some value for feed evaluation because it reflects diet digestibility and can be measured with relative ease (NRC, 1996). Chemical composition of feed ingredients is a major determinant of DE, with positive effects of ether extract and negative effects of fiber and ash. Stanford et al. (2003) reported that barley DE was significantly correlated with barley starch (r=0.73, P<0.05) and ADF content (r=-0.71, P<0.05), and tended to be correlated with NDF content (r=0.67, P=0.07).

Acidosis

Barley based finishing diets are associated with a high risk of acidosis because of the starch content and digestion characteristics of barley grain. When high levels of starch are consumed by the animal, more VFA are produced in the rumen, leading to a reduction in rumen pH. This reduction in rumen pH and the collection of associated symptoms has been commonly referred to as acidosis. Stock and Britton (1993) defined acidosis as an array of biochemical and physiological stresses caused by rapid production and absorption of ruminal organic acids and endotoxins when an animal over consumes a diet of readily fermentable carbohydrates, and can be classified as acute or subacute. Subacute acidosis is extremely difficult to diagnose, as the primary symptom is a reduction in feed intake (Fulton et al., 1979). However, lethargy, diarrhea, panting, excessive salivation, and general signs of discomfort may also be indicative. Factors that may contribute to subacute acidosis include grain source and extent of processing, roughage level, particle size, bunk space, or disruptions to regular feed delivery (Fulton et al., 1979).

The primary challenge with subacute acidosis is that a reduction in feed intake by an individual animal is difficult to observe in a pen setting (Fulton, et al., 1979). Factors that may affect the severity of an acidosis challenge include roughage level, ethanol coproduct inclusion, ionophore inclusion, and buffering agents. Ionophores are commonly fed to feedlot cattle to improve feed efficiency (Richardson et al., 1976; Goodrich et al., 1984). Ionophores may enhance the efficiency of ruminal fermentation by shifting microbial profiles (Bergen and Bates 1984), stabilizing ruminal pH (Nagaraja et al. 1982), and reducing feed intake variation (Burrin et al., 1988; Stock et al., 1995).

Cooper et al. (1999) conducted four metabolism and two finishing trials to determine the effects of imposed feed intake variation on acidosis and performance of finishing steers. In Metabolism Trial 1, four ruminally fistulated steers were limit-fed and subjected to either a constant amount of feed per day (C) or low intake variation of .7 kg/d (LV). No treatment differences were found for intake or measures of acidosis. Metabolism Trial 2 was conducted similarly to Metabolism Trial 1 with treatments of C and high intake variation of 1.4 kg/d (HV). Treatment HV increased (P<0.05) acidosis, as indicated by the area of ruminal pH below 5.6. In Metabolism Trial 3, four steers were fed at ad libitum levels of intake and subjected to three levels of intake variation: ad libitum intake with no imposed intake variation (AL), LV of .7 kg/d, and HV of 1.4 kg/d. No treatment differences were found. In Metabolism Trial 4, six ruminally fistulated steers were fed at ad libitum levels and subjected to three levels of intake variation: AL, LV of .9 kg/d, and HV of 1.8 kg/d. Average ruminal pH increased (P<0.05) and area of ruminal pH below 5.6 decreased (P<0.05) as level of intake variation was increased. In Finishing Trial 1, 75 steers were assigned to eight pens and two treatments: AL or HV of 1.8 kg/d. Dry matter intake increased (P<0.05) from AL to HV. Daily gain and G:F were not affected by treatment. In Finishing Trial 2, 94 steers were assigned to 12 pens and two treatments: AL or HV of 1.8 kg/d. No treatment differences were noted in DMI, ADG, or G:F. The results of these trials indicated that intake variation of up to 1.8 kg/d does not increase acidosis or decrease performance of finishing steers fed at ad libitum levels of intake of a corn based diet.

Dried Distillers Grains Plus Solubes

Production of Distillers Grains

Distillers grains plus solubles (DGS) are a co-product of dry milling of grain (corn, wheat, barley, or sorghum) to make ethanol (Klopfenstein et al., 2008). Rapid expansion of the US ethanol industry has prompted a number of cattle producers in the US and Canada to incorporate DGS in feedlot rations as a protein source or as an energy source (>20% diet DM) (NRC, 1996; Klopfenstein et al., 2008). During the dry milling process, grain is ground, soaked, and cooked before enzymes followed by yeast are added to the mixture to ferment sugar into ethanol. Ethanol is subsequently removed by distillation, and the resulting stillage is centrifuged to separate distillers grains (solid fraction of the stillage) from distillers solubles (liquid portion of the stillage). Following evaporation of water from solubles, distillers grains and condensed solubles are blended together to make wet DGS(WDGS, 30% DM) or dry (DDGS, 90% DM).

As a result of the lower moisture content, DDGS have a longer shelf life than WDGS and reduced transport cost due to less moisture being hauled. These reduced transport costs of DDGS compared to WDGS has led to DDGS being more commonly fed in Canada than WDGS. The price of WDGS is typically less than the price of DDGS (Waterbury and Mark, 2008), because there is a competing demand for DDGS in poultry and swine rations. In addition, drying DGS to produce DDGS represents an additional cost to the ethanol plant, and thus increases the cost of DDGS compared to WDGS. Although DGS may be an attractive feedstuff from an economic perspective, some concern has arisen regarding the inconsistency of nutrient composition (Buckner et al., 2011b).

Nutrient Composition of Distillers Grains

Corn grain is approximately two-thirds starch, and only the starch is removed during the fermentative process of ethanol production, therefore all other nutrients are concentrated three-fold. For example, CP increases from approximately 9% in the corn grain to approximately 27% in the whole stillage fraction (DM basis). Nutrient composition of DGS is approximately 31% CP (70% of CP is undegradable intake protein), 11.9% ether extract, 33% NDF, 4.5% ash, 0.84% P, and 0.77% S (Buckner et al., 2011b). The increased P content compared to corn has implications which will be discussed in later sections of this chapter. Because DDGS are a byproduct of a process designed for ethanol production, factors such as selection of grains, type of fermentation (continuous or batch), and drying temperature and duration (Carpenter, 1970; Olentine, 1986) can influence the nutritional and physical properties of DDGS.

Effect of Dried Distillers Grains on Finishing Cattle Performance

Respondents to a feedlot nutritionist survey conducted by Vasconcelos and Galyean (2007) indicate that distillers grains plus solubles (DGS) are the most common ethanol byproduct used by cattle feeders. Experimental data indicate that up to 50% of diet DM may be replaced with DGS in feedlot diets and improve cattle performance (Klopfenstein et al., 2008b). However, the nutritionists' surveys indicated the average DGS inclusion rate is 20% (DM basis) with a range of 5 to 50% of the diet DM (Vasconcelos and Galyean, 2007). Most of the research involving DDGS has been in corn-based diets. Because DDGS contains significant amounts of fiber and essentially no starch, adding this commodity to barley-based diets may have the additional benefit of moderating and stabilizing rumen pH, thus reducing the potential for acidosis.

Various authors have conducted feeding trials with a direct comparison of WDGS and DDGS (Ham, et al. 1994a; Lodge, et al. 1995; Trenkle 1996; Mateo, et al. 2004; and Cole, et al. 2006). Each of these trials concluded that, on average, feeding WDGS improved feed efficiency compared to feeding DDGS. Loy and Miller (2002) offered several explanations for the improvement in feed efficiency including: moisture content, a reduction in the incidence of subacute acidosis, and heat damage that occurs during the drying process. Klopfenstein (1991) reported that energy values are reduced when DGS are severely heat damaged; although this extreme is probably rarely the case.

At the University of Nebraska-Lincoln beef research feedlot, 4 trials with 66 pens representing 581 steers fed corn-based diets have been conducted evaluating DDGS in finishing diets (Ham et al., 1994; Bremer et al., 2011; Buckner et al., 2010; Nuttelman et al., 2010; Sarturi et al., 2010). A reduction in feed efficiency and in energy content as moisture is removed from WDGS has been observed in three of the trials evaluating both WDGS and DDGS in the same trial (Ham et al., 1994; Nuttelman et al., 2010; Sarturi et al., 2010). Nuttelman et al. (2010) evaluated feeding various dietary inclusion levels of WDGS, modified DGS (MDGS), and DDGS in the same trial and found that the energy value of WDGS was greater than MDGS, and both WDGS and MDGS were greater than DDGS. Nuttelman et al. (2010) also reported increased DMI as moisture content of DGS decreases, with no difference in ADG, suggesting an energy response.

Feeding trials have also been conducted to determine the optimal inclusion level of DDGS in finishing diets. A Texas Tech survey suggests that the average DGS inclusion rate among feedyards is 20% of diet DM (Vasconcelos and Galyean, 2007). Bucker et al. (2008) observed a quadratic trend for ADG, no effect on DMI, and linearly

increasing G:F when DDGS inclusion levels were increased from 0% to 40%. In contrast, Mateo et al. (2004) reported that increasing DDGS inclusion from 0% to 40% had no effect on ADG, decreased DMI, and a slight increase in G:F. Because DDGS contains significant amounts of fiber and essentially no starch (less than 5% of DM), adding this commodity to barley-based diets may have the additional benefit of moderating and stabilizing rumen pH, thus reducing the potential for acidosis (Anderson et al., 2011). Walter et al. (2010) replaced 20% or 40% of barley grain in the finishing diet with wheat or corn-based DDGS and found that replacement of barley grain with corn or wheat-based DDGS up to 40% of the diet DM can lead to superior performance (improved gain: feed or reduced days on feed) with no detrimental effect on quality grade or carcass. Cattle fed corn DDGS exhibited a quadratic increase in G:F, and as a result, a quadratic increase in calculated NEg of the diet was observed as corn DDGS levels increased. Anderson et al. (2011) fed 0, 12, 24, and 36% (DM basis) DDGS in barleybased diets and reported optimal performance and carcass characteristics at 24% of diet DM. Intake tended to increase linearly as DDGS level increased. Gains were greater with DDGS in the diet and improved linearly as DDGS level increased. Feed efficiency was unaffected (P=0.63) by DDGS level.

The inclusion of distiller's grains in finishing diets appears to have variable effects on carcass quality. Buckner et al. (2007) found that increasing the DDGS inclusion level did not impact any carcass characteristic (aside from HCW), where measured characteristics included: marbling score, ribeye area, rib fat, and calculated yield grade. Walter et al. (2010) observed a quadratic increase in dressing percentage as corn DDGS inclusion level in barley-based diets increased, but other carcass traits were

not affected by DDGS inclusion level. In contrast, Anderson et al. (2011) reported that carcass traits reflected increased gain with linear increases in dressing percentage, fat thickness, marbling scores, YG, and KPH, as well as an increase in the percentage of USDA Choice carcasses with DDGS level in steers fed barley based diets.

Economic Factors Associated with Feeding Distillers Grains

Ration consistency is vital for cattle growth and feed efficiency, as well as to reduce the incidence of digestive disorders (Loy, et al. 2005). Some plants may provide product specifications with guaranteed nutrient contents; however, these values are only estimates of the minimum or maximum nutrient content (Tjardes and Wright, 2002). Evaluating the nutrient content of each load delivered to the feedyard would provide an accurate estimate of nutrients delivered to cattle, but this is impractical and expensive. Because DDGS are a byproduct of the ethanol industry, both timing of delivery and nutrient content can be highly variable (Buckner et al., 2011a).

Transportation costs must be incorporated into ration cost. Therefore, distance to the nearest ethanol plant or DDGS source compared to grain source is important to managers making decisions on which commodities price into rations, and at what inclusion level.

Lastly, managers must consider storage requirements and capabilities if DDGS are to be incorporated into the feedlots rations, as this can be a challenge. Because supply can be variable, and the shelf life of DDGS is considerable due to the low moisture content and will not mold as easily as MDGS or WDGS, having sufficient storage space may be valuable. In addition, the lower moisture content may limit the risk of freezing during winter months. However, the particle size of DDGS is relatively small

and thus the commodity is best stored in a wind-protected area to minimize shrink losses (Tjardes and Wright, 2002)

Monensin

General Information on Monensin

High grain diets increase digestive and metabolic disease (Galyean and Rivera, 2003). Ionophores are one of the primary feed additives used in the feedlot industry to manage these challenges. Monensin (Rumensin®, Elanco Animal Health, Indianapolis, Indiana) is an ionophore commonly fed to feedlot cattle. Monensin is a biologically active compound (Haney and Hoehn, 1967) produced by Streptomyces cinnamonensis that alters rumen fermentation. Increased molar percentages of ruminal propionic acid when monensin is fed have been reported by many investigators (Potter et al., 1974; Richardson et al., 1974; Utley et al., 1976; Dinius et al., 1976; Perry et al., 1976). As an ionophore, monensin's primary effect is to facilitate the passage of ions across cell membranes. Monensin has a strong affinity for sodium (Na) and potassium (K), increasing Na concentration within the cell, while increasing K concentration outside the cell (Pressman, 1976), and increasing the activity of the Na-K pump (Smith and Rozengurt, 1978). Since its use in feedlot diets in the US was approved in December of 1975, monensin has gained wide acceptance by the cattle feeding industry. Many experiments have been conducted to evaluate the influence of monensin on performance of feedlot cattle.

Feed efficiency response to monensin supplementation has been variable, but an improvement is often observed. The proposed mechanism for this improvement is that monensin alters the proportions of volatile fatty acid (VFA) end products in both *in vitro*

and *in vivo* ruminal fermentations, specifically increasing the molar proportion of propionic acid while decreasing acetic and butyric acids (Richardson et al., 1976). In addition, monensin stabilizes ruminal pH (Nagaraja et al. 1982), and reduces feed intake variation (Burrin et al., 1988; Stock et al., 1995).

Cooper et al. (1997) conducted an experiment with six ruminally fistulated steers to evaluate the effect of monensin and feed intake variation on ruminal pH. Steers were adapted to a 92.5 percent concentrate diet and subsequently subjected to three levels of intake variation: ad libitum, intake variation of 2 lb/day, and intake variation of 4 lb/day. Intake and ruminal pH were monitored throughout the trial. Dry matter intakes during the finishing period averaged 28.0 Ib per day and ADG for the six steers during the trial was 4.0 lb. Steers receiving monensin consumed less feed over the grain adaptation period (P<0.05). Average daily ruminal pH was not affected by monensin. Ruminal pH was relatively constant from step one through step four, averaging 5.87. Daily magnitude of ruminal pH change was not affected by monensin. Therefore, results of the grain adaptation period indicate that monensin allowed steers to move on feed more gradually, but did not affect DMI by the second five days on the finishing diet. In addition, when runimal pH was plotted over time, monensin reduced the area of ruminal pH that fell below 5.6 for the first and second five days on finisher, indicating less acidosis while adapting to the finishing diet. Area of ruminal pH below 5.6 tended to be greater (P=0.07) for the steers on control than on monensin indicating more subacute acidosis with the controls. Therefore, results of the finishing period indicate that the use of monensin elevates average ruminal pH and decreases area of ruminal pH below 5.6,

while stabilizing rate of intake and daily ruminal pH fluctuation at high levels of feed intake variation.

Monensin and Feedlot Performance

Goodrich et al. (1998) summarized 228 trials that included 11,274 cattle fed diets containing monensin or a control diet. Cattle fed monensin cattle gained 1.6% faster than cattle fed control diets. Monensin-fed cattle consumed, on average, 6.4% less than control cattle. Feed efficiency was improved by 7.5% when monensin was fed. Standard deviations for ADG ($1.6\pm8.5\%$ greater ADG), DMI ($6.4\pm5.0\%$ lower DMI) and feed/100 kg of gain ($7.5\pm6.5\%$ less feed/100 kg gain) indicate considerable variability in the performance response to monensin. Carcass characteristics of cattle fed control or monensin-containing diets are were also evaluated in their analysis. Rib eye area was the only outcome to show a positive response (0.61%) to monensin inclusion. Dressing percentage, marbling score, fat depth, quality grade and yield grade were negatively affected by feeding monensin (-0.38, -0.39, -0.24, -0.69 and -0.31%, respectively). Standard deviations for percentage change in carcass characteristics indicate that the effects of monensin on carcass characteristics are highly variable, similar to feedlot performance.

Goodrich et al. (1976) summarized data from 29 experiments that were conducted to determine effects of monensin level on feedlot performance and carcass characteristics. Steers and heifers, yearlings and calves (n=3,042) were involved in the 29 growing, finishing and growing-finishing trials. Cattle fed commonly used concentrations of monensin (11, 22, 27.5 or 33 g/t had similar rates of gain, with the exception of cattle fed 33 g/t as these cattle had lower ADG than those fed 11 g/t. Intake declined as monensin

concentration increased. Feed to gain ratios were 7.89, 7.41, 7.31, 7.08, and 7.23 kg for cattle fed 0, 11, 22, 27.5 or 33 g/t, respectively. Carcass characteristics were not affected by the feeding of monensin in these 29 experiments.

Goodrich et al. (1998) summarized data from six trials using regression techniques and cattle performance at equal dietary protein content to examine the protein requirements of cattle fed monensin. The authors noted that the CP requirement of 246 kg steers gaining 1.0 kg/d is 11.6% (NRC, 1976). The CP concentration where improvement in daily gain was optimized for monensin fed cattle was 11.2%. Feed intake of cattle fed monensin was minimized at 12.0% CP. Feed efficiency was optimized when monensin was fed in a diet that contained 11.2% CP. The authors concluded that these data support the theory that monensin spares dietary protein from ruminal degradation.

Monensin Level and Feedlot Performance

Raun et al. (1976) conducted a study to define the dose response relationships between 0, 2.7, 5.5, 11, 22, 33, 44 and 88 mg/kg monensin and ADG, DMI, and feed efficiency. All dosages except 88mg/kg resulted in ADG that was equal to or greater than 0 mg/kg. The authors found that feed consumption decreased progressively with increasing monensin dosage, with a 3.5% reduction at 11mg/kg and a 13.1% reduction at 33 mg/kg. All monensin treatments resulted in improved feed efficiency. At 11 and 33 mg/kg feed efficiency was improved 10% and 17%, respectively.

Boling et al. (1977) fed 0, 25, 50, or 100 mg monensin per head to determine the effect of monensin level on growth, efficiency, volatile fatty acids and carcass

characteristics of steers in a 157-day finishing study involving steers on Kentucky bluegrass clover pasture. Average daily gains were 0.55, 0.55, 0.73 and 0.68 kg, respectively, and were greater for steers fed 50 or100 mg monensin than for the control and the steers fed 25 mg. As monensin level increased, so did ruminal propionate. In a second study, the authors allotted 96 steers to one of four treatments and fed 0, 100, 200 or 300 mg monensin per steer per day with 4.54 kg of grain, plus corn silage *ad libitum*. Average daily gains for were: 1.14, 1.26, 1.23, and 1.18 kg/day, respectively. Intake tended to decrease as level of monensin fed increased. An improvement in feed efficiency was observed for all groups fed monensin compared to the control. Molar percentages of acetate and butyrate decreased, and propionate increased as monensin level increased. Carcass characteristics were not influenced by level of monensin fed in this study, but steers fed 300 mg per day tended to have lower marbling scores, smaller rib eve area and less fat over the rib.

Stock et al. (1990) conducted feedlot trials to evaluate interactions among grain type (grain sorghum, corn or wheat), roughage level and monensin level (0 or 27.5 mg/kg). A grain type by roughage level by monensin level interaction was observed for feed efficiency. The addition of 27.5 mg of monensin per kilogram of the 0% roughage-DRC diet tended to improve feed efficiency (0.153 vs 0.163 for 0 mg and 27.5 mg monensin, respectively), but the addition of monensin to the 7.5% roughage-DRC diet tended to depress feed efficiency (0.158 vs 0.148 for 0 mg and 27.5 mg, respectively). The addition of monensin to the dry-rolled wheat diet also improved feed efficiency (0.141 vs 0.150 for 0 mg and 27.5 mg, respectively). In these experiments, the value of feeding monensin was variable both across grain types and roughage inclusion.

Stock et al. (1995) evaluated the effects of feeding monensin at 0, 22, or 33 mg/kg in four commercial feedlot experiments, and also conducted an individual animal feeding trial. Feeding monensin improved feed efficiency by 4% in the feedlot studies; but no differences were detected between 22 and 33 mg/kg monensin treatments. Small differences in DMI, ADG, and feed efficiency were observed between individually-fed steers fed 0 or 27 mg/kg of monensin. Feeding monensin also reduced DM1 variation in individually fed steers. Thus, commercial feedlots may not observe a reduction in intake variation due to the pen average masking individual animal variation.

Erickson et al. (2003) conducted two commercial feedlot experiments and one metabolism study to evaluate the effects of monensin concentrations and bunk management strategies on performance, feed intake, and ruminal metabolism. In the feedlot experiments, 1,793 and 1,615 steers were used in Exp. 1 and 2, respectively, with 18 pens in each experiment (six pens per treatment). Three treatments were evaluated in each experiment: ad libitum bunk management with 28.6 mg/kg monensin, clean bunk management with 28.6 mg/kg monensin, or clean bunk management with 36.3 mg/kg monensin. Monensin concentration had no effect on carcass-adjusted performance in either experiment, and minimal effects on carcass characteristics. In Exp. 1, feeding 36.3 mg/kg monensin increased dressing percentage and decreased the percentage of USDA YG1. In Exp. 2, feeding 36.3 mg/kg monensin decreased the percentage of carcasses grading Choice, increased the percentage of USDA YG3 carcasses, tended to increase the percentage of carcasses grading Select, and tended to decrease the percentage of USDA YG2 carcasses. The authors hypothesized that the changes in USDA quality grade were likely a reflection of intake between bunk management strategies.

Monensin, Grain Source and Forage Level

Surber and Bowman (1998) conducted two experiments to determine the effects of monensin addition on digestion of high-concentrate diets based on corn or barley and to identify any interactions between grain source and monensin addition. The authors used a replicated *in vitro* experiment with a 2 x 4 factorial arrangement to evaluate monensin addition (0 or 72 mg/kg in vitro substrate) and grain source (corn, Gunhilde barley, Harrington barley, or Medallion barley). Triplicate tubes for each treatment were incubated for 0, 3, 6, 9, 12, 18, 24, and 30 h, and rate and extent of in vitro dry matter digestibility (IVDMD) were determined. Four ruminally and abomasally cannulated steers were used in a 4 x 4 Latin square design with a 2 by 2 factorial arrangement of treatments to test the effects of monensin addition (0 vs 270 mg/animal daily) and grain source (corn vs Medallion barley). An interaction was present between monensin addition and grain source for IVDMD during 3 through 9 h of incubation. Monensin increased the IVDMD of Gunhilde and Medallion barley, but it decreased the IVDMD of Harrington. Corn IVDMD was not affected by monensin addition. Steers fed Medallion barley had greater microbial protein synthesis, rate of in situ DM and starch disappearance, greater ruminal and postruminal digestion of starch, ruminal total VFA concentrations, and total tract digestion of DM, OM, and starch compared to steers fed corn. Monensin addition decreased ruminal digestion of feed N and ruminal proportions of acetate and butyrate, but increased the ruminal proportion of propionate.

Zinn et al. (1994) conducted a feedlot growth-performance trial and a metabolism trial to evaluate the interaction of forage level (10 vs 20%) and monensin (0 vs 31 mg/kg, DM basis) on utilization of a steam-flaked corn-based finishing diet. No treatment

interactions on feedlot cattle growth performance or site and extent of digestion of OM, ADF, N, and starch were observed. Monensin supplementation did not influence ADG, DMI, feed efficiency, estimated NE value of the diet, or ruminal and total tract digestibility of OM, ADF, and starch. Monensin decreased passage of microbial N to the small intestine by 14.5% and ruminal digestion of feed N by 10.4%. Ruminal pH tended to be slightly lower (1.9%) when monensin was fed. Monensin did not affect ruminal molar proportions of acetate and butyrate. However, there was an interaction between forage level and monensin on ruminal molar proportions of propionate. In the low forage diet, molar proportions of propionate were increased by 9.4% with monensin supplementation. In contrast, ruminal molar proportions of propionate in the high-forage diet were 5.5% lower with supplemental monensin. Monensin did not affect estimates of methane production. Decreasing the forage in the diet from 20 to 10% increased ADG by 10.8%, feed efficiency by 11.6%, and diet NE by 11.3%. Ruminal digestibility of ADF, OM, and starch were not affected by forage level. However, ruminal digestibility of feed N was 20% greater with the high-forage diet. Increasing forage level in the diet decreased total tract digestion of OM by 2.4%, DE by 2.7%, ME by 4.8%, increased ruminal pH by 4.4%, ruminal molar proportions of acetate by 13.0%, decreased ruminal molar proportions of propionate by 10.2%, and increased estimated methane production by 19.4%. The authors concluded that failure of monensin to elicit a performance response in feedlot steers fed a steam-flaked corn based finishing diet is not due to differences in the diets forage level but perhaps due to the characteristics of the forage.

Monensin and Acidosis

Nagaraja et al. (1981) reported that intra-ruminal administration of monensin at 1.3 mg/kg BW was effective in preventing experimentally induced acidosis in cattle. In that experiment, control cattle that did not receive monensin developed acute acidosis with typical signs of dullness, lowered blood pH, increased blood lactate, diarrhea, hyperventilation, and dehydration. Cattle that received monensin exhibited no clinical signs of acidosis.

Burrin and Britton (1986) conducted a steer metabolism study to measure changes in ruminal and blood components in response to monensin level following an abrupt switch from forage to a concentrate diet. Six ruminally cannulated crossbred steers weighing an average of 373 kg were fed 0, 150 or 300 mg/animal daily monensin in a replicated 3 x 3 Latin square design. In all treatments, ruminal pH declined to 5.4 to 5.6 12 h post-feeding, suggesting that steers had experienced subacute acidosis. Also in the first 12 h post-feeding, all treatments exhibited nearly a twofold increase in total ruminal volatile fatty acid (VFA) concentration. During the entire 48 h period, there were no differences in blood pH, HCO₃ or ruminal lactate, although there was a trend of higher ruminal and blood lactate associated with increased level of monensin supplementation. Feeding higher levels of monensin resulted in higher pH and propionate with lower acetate and butyrate concentrations. Increasing the level of monensin fed resulted in a reduction of total ruminal VFA concentrations. Ruminal pH was highly correlated to total ruminal VFA concentrations (r=-0.69) and somewhat correlated to lactate concentrations (r=-0.14). Results from this study indicate the significance of total ruminal organic acid concentration rather than ruminal lactate concentration during

subacute acidosis. Feeding monensin resulted in a higher ruminal pH by reducing concentrations of VFA.

Erickson et al. (2003) conducted a metabolism experiment with eight fistulated steers in a replicated 4 x \(\to 4 \) Latin square acidosis challenge experiment. The acidosis challenge involved feeding 125% of the previous day's DMI, 4 h later than normal. Treatments included 0, 36.7, 48.9, or 36.7 mg/kg monensin until challenged, and increased to 48.9 mg/kg on the day of the challenge and continued for 4 d. Each replicate of the Latin square was managed with separate bunk management strategies (clean bunk or *ad libitum*). Feeding any concentration of monensin increased number of meals and decreased DMI rate (%/h) for the 4 d following the acidosis challenge. Meal size, pH change, and pH variance were lower for steers fed monensin managed with clean bunk management. In contrast, no monensin effect was observed for steers fed *ad libitum*. The authors concluded that feeding monensin helps moderate intake patterns for individual animals, and that increasing concentration above currently approved levels had little benefit.

Nutrient Mass Balance

General Information on Manure as a Fertilizer

The application of manure onto agricultural land as fertilizer is a common practice in most agricultural operations. High levels of nitrogen (N) and phosphorus (P) creates the potential for excess nutrients in manure to provide nutrients that grain producers would otherwise obtain from commercial fertilizers. Establishing this type of relationship provides two advantages 1) an outlet for the manure from the feedlot, and 2) provide less expensive nutrients for crop production. Feedlot manure can supply all the

essential nutrients and restore depleted organic matter to the soil (Eghball and Power, 1999). It is important to note that application of manure on agricultural land is not without environmental risk. There is a risk of groundwater contamination through leeching. Excess nitrates, salts, pathogens, odors, and weed seeds in manure provide a potential source of pollutants for water, air, and land (Eghball and Power, 1994). Nutrient management strategies and regulations provide for the optimal management of animal waste materials containing nutrients that may be applied to land. In addition, these strategies protect water sources while maximizing the economic and biological value of the nutrients.

Methods to Reduce N Losses from the Feedlot

Many feedlots opt to clean pens at least once annually. By the time the pen is cleaned and hauled to be piled, the manure has lost approximately 50% of the N that was originally excreted, mostly to NH₃ volatilization (Gilbertson et al., 1971). Several methods to reduce N losses from manure have been evaluated. The first method is to alter the C:N ratio of manure by feeding a less digestible feedstuff (additional fiber). The excretion of carbon-containing OM increases with increased dietary fiber, therefore increasing the C:N ratio on the pen surface. Bierman et al. (1999) fed diets containing three levels of fiber to feedlot steers: 1) 41.5% wet-corn gluten feed (WCGF) with 7.5% roughage, 2) 7.5% roughage, and 3) 0% roughage to determine the effect of carbohydrate source on reducing the loss of N by changing the distribution of N from urine to feces or by increasing OM on pen surface. Intake of N was greatest for WCGF, followed by the 7.5% roughage diet, and lowest for cattle fed 0% roughage. Retention of N was similar, thus the cattle that consumed the most N subsequently excreted more N. Cattle fed

41.5% WCGF excreted the most N, followed by cattle fed the 7.5% roughage diet, and cattle fed 0% roughage excreted the lowest amount of N (20.8, 18.5, 16.3 kg, respectively). The amount of N removed in the manure was greatest for cattle fed WCGF at 3.9 kg, intermediate for cattle fed 7.5% roughage at 2.3 kg, and lowest for cattle fed 0% roughage at 1.5 kg. As a follow up, Erickson and Klopfenstein (2001) conducted a study to determine if an increase in OM excretion would reduce N losses by feeding 0, 15, or 30% corn bran (less digestible component of WCGF). In the winter/spring trial, OM in manure was increased 51% and 105% for cattle fed 15% and 30% bran, respectively, compared to the cattle consuming 0% bran. Losses of N decreased linearly by 14.5% and 20.7% for the 15% and 30% bran diets compared to 0% bran. Manure N increased linearly by 67% and 98% with the cattle consuming 15% and 30% corn bran. Conversely, in the trial conducted in summer/fall, OM in manure only increased 15% and 25% for the cattle consuming the 15% and 30% corn bran diets, respectively, and was not enough to affect manure N or N losses. Even though N volatilization was not different in the trial conducted in the summer/fall, there was still an increase in the measured C:N ratio of the manure that was removed, suggesting that adding corn bran has variable effects on manure N retention depending on the time of year. Adding corn bran to a feedlot ration at 15% to 30% during the cooler winter months could decrease N volatilization, but was not effective in the warmer summer months.

A second method to increase the C:N ratio of manure is to directly add carbon to the pen surface in the form of bedding. Adams et al. (2003) evaluated direct addition of OM to the pen surface versus indirect addition through dietary manipulation. Two trials, one in the summer and one in the winter included a 0% corn bran diet; a diet designed to

decrease digestibility and increase OM excretion (30% corn bran); and a management treatment where cattle were fed the 0% corn bran diet and sawdust was applied to the pen surface on a weekly basis at a rate calculated to match OM excretion by the 30% corn bran fed cattle. During the winter trial, adding OM to the pen surface either directly (sawdust) or indirectly (feeding 30 % corn bran) decreased the amount of N lost and increased the about of N in the manure. A 20 to 23% reduction in N loss was observed for cattle fed 30% corn bran and in pens that had received sawdust, respectively, over the pens of cattle fed 0% corn bran. Fecal N was highest for the cattle consuming the 30% corn bran diet, suggesting that the route of N excretion shifted from urinary urea-N to fecal N.

Lory et al. (2002) applied a 2:1 ratio of sawdust to fecal DM to the pen surface from June to October in an attempt to reduce N losses. Volatilization loss of N was reduced by 21% as compared to pen surfaces that received no bedding. Bussink and Oenema (1998) and Shi et al., (2001) have added straw to reduce N losses with variable results. Although adding carbon to the pen surface improves the C:N ratio; this may have limited application due to management challenges.

Feed additives may also be used to reduce N losses. Doerr et al. (2012) performed two experiments to evaluate the effect of Micro-Aid in WDGS diets on feedlot performance and nutrient mass balance. A WINTER experiment was conducted from November to May, and a SUMMER from May to November. Micro-Aid contains saponins that have neutral detergent and surfactant properties and is excreted with feces and enhances microbial conversion of undigested nutrients into organic N compounds.

Feeding Micro-Aid did not affect DMI, ADG, F:G, or carcass characteristics in the WINTER or SUMMER. Intake, retention, and excretion were also not different. Total N in manure was greater for steers fed Micro-Aid in the WINTER, but was not different in the SUMMER. Loss of N to volatilization was greater for cattle that did not receive Micro-Aid in the WINTER, but was not different in the SUMMER. Total DM removed from the pen was numerically greater for steers fed Micro-Aid in the WINTER, whereas OM removed from the pen was numerically greater for steers that did not receive Micro-Aid. Intake, retention, and excretion of P were also similar in both experiments. Manure P was greater for cattle fed Micro-Aid in the WINTER, but was not different in the SUMMER. Micro-Aid was therefore effective in increasing N retention by the animal, as well as reducing the amount of N volatilized in the cooler winter months, but did not have the same effect in the warmer summer months.

Other methods to reduce N losses include increasing the frequency of pen cleaning. Higher ambient temperatures during the summer months result in more rapid volatilization of N, so increasing the frequency of manure removal reduces exposure of manure N to air which would, in turn, reduce N losses. Wilson et al. (2004) conducted two experiments- one in the summer of 2001, and the second in the summer of 2002, evaluating the impact on N volatilization when feedlot pens were cleaned monthly or only once at the end of the feeding period. A total of 4 cleanings were performed for the monthly cleaning treatment (approximately every 28 days). The amount of DM, OM, and N removed were increased if pens were cleaned monthly compared to a one-time cleaning at the end of the feeding period. Manure N per steer increased 3.95 kg for the monthly cleaning, which represented a 69% increase, compared to manure N removed in

the end cleaning treatment. There was an improvement in C:N ratio due to the increase in OM in manure when manure was collected more frequently. By cleaning pens monthly, total OM removal per steer increased by 91.4% in 2001 and 66.8% in 2002 above total OM removed at the end of the cleaning period.

Farran et al. (2004) evaluated the effect of both dietary manipulation and management on N losses from open feedlot pens during both winter and spring feeding periods. To evaluate if there was an interaction between frequency of pen cleaning and diet on N losses, the researchers used a 2 x 2 factorial arrangement of treatments. Pens were cleaned monthly or only once at the end of the feeding period. Both pen cleaning treatments were fed 0 or 30% corn bran (DM basis). A dietary treatment by pen cleaning frequency interaction was observed for N balance. Nitrogen losses decreased and manure N increased for cattle fed 30% corn bran compared to 0% corn bran if pens were cleaned monthly. Feeding 30% corn bran had no effect on manure N, but increased N loss when pens were cleaned once at the end of the feeding period. Feeding 30% corn bran increased the C:N ratio of manure and increased the amount of N recovered in manure, regardless of how often pens were cleaned.

Distillers Grains and Nutrient Mass Balance

Kissinger et al. (2006) conducted a commercial feedlot study to determine manure nutrient flow in six feedlots using a corn and by-product based diet with an average P content of 0.39% (DM basis), and a range of 0.34 to 0.48%. Mass balances for N and P were conducted for each pen. The average feed nutrient intake was 0.24 kg N/head/day (29.0 + 3.4 kg/animal fed) and 0.04 kg P/head/day (4.9 + 1.0 lb/animal fed). Based upon

averages from the 6,366 head of cattle, 11.5% of the feed nitrogen and 16.9% of the feed phosphorus were retained by the animal with the remaining nutrients excreted. The harvested manure averaged 73% dry matter and 28% organic matter. Based upon these data, 31% of the excreted nitrogen or (7.8 lb/animal fed) and 90% of the excreted phosphorus (3.7 kg/animal fed) were removed in manure at cleaning.

Kissinger et al. (2007) characterized beef feedlot manure under open lot commercial conditions according to: 1) harvested manure quantities and characteristics; 2) impact of factors such as feeding program, season, and management on harvested manure; and 3) mass balance for nitrogen (N) and phosphorus (P). Most recent estimates of quantities and characteristics of harvested manure from commercial feedyards date back to the early 1970s. In addition, harvested manure is impacted by weather, feeding program, season, and pen management decisions. Data from six commercial feedlots (representing 6,366 head of cattle) suggested that 33% of excreted N (65 g/animal daily) and 91% of excreted P (32 g/animal daily) are harvested as manure on average and that current standard estimates published by ASAE (2005) and NRCS (1992a) overestimate harvested manure N and P. Additionally, significant variation was observed among feedlots and is driven by ration nutrient concentration (P only), pen conditions prior to and during manure harvest (N and P), and management choices relative to use of manure in lot maintenance (N and P). The variation would suggest that nutrient planning estimates for open lots would need to be based upon farm specific data as opposed to typical or standard values. A pen based nutrient balance for a beef cattle feedlot suggested that pen outputs as finished animal, harvested manure, and nutrient losses represent 31%, 23%, and 47%, respectively, of all pen N inputs and 38%, 57%, and 5%,

respectively, of all pen P inputs. Inputs included nutrient content of all animals and feed entering a feedlot pen over a grow-out period.

Feeding less digestible feedstuffs has been successful in reducing the amount of N lost from the pen surface by increasing hindgut fermentation, which results in an organic N in the feces rather than urea in the urine, a more volatile form of N (Bierman et al., 1999; Adams et al., 2003; Farran et al., 2006). As previously mentioned, the high phosphorous content in DGS makes manure composition an important consideration when determining optimal DGS inclusion levels. Tomlinson et al. (1996) and Morse et al. (1992) note variation in nutrient intake is the single most important contributor to overall variation in nutrient excretion, and thus changes in dietary nutrient intake levels will directly impact the amount of nutrient excreted in the manure. Therefore, distiller's grains which are high in both CP and P, will directly impact the amount of N and P excreted in the manure, thereby impacting manure management costs.

Several feeding studies have evaluated N and P excretion levels under a variety of DGS inclusion levels. For example, Benson et al. (2005) found that P excretion increased by 453 mg/kg as the DDGS inclusion rate was increased from 0% to 35%. Meyer et al. (2006) conducted a study evaluating P excretion when WDGS inclusion rates varied from 0% to 20%. The authors found that P excretion increased from 13.2 g/d to 19 g/d as WDGS level increased. Thus, as dietary DGS inclusion level increases, N and P excretion also increase.

Most of the mass balance studies that have been conducted previously have involved the use of WDGS as opposed to DDGS. Wet DGS improves feedlot

performance, and due to a higher NDF content (37%) than corn, increases OM content of manure (Klopfenstein et al., 2008). Feeding WDGS also improves fertilizer value of manure (Bremer et al., 2008). Because WDGS is less digestible, it reduces the amount of N lost from the pen surface by promoting hindgut fermentation, resulting in excretion of organic N in the feces rather than the more volatile form or urinary urea (Bierman et al., 1999; Adams et al., 2003; and Farran et al., 2006).

Luebbe et al. (2008) performed two experiments to evaluate the impact of WDGS on feedlot performance and nutrient mass balance. A WINTER experiment took place from November to May and a SUMMER experiment from June to October.

Experimental groups included 0, 15, and 30% inclusion of WDGS in the diet (DM basis) replacing corn. Intake and ADG increased linearly with WDGS level in the WINTER, but were not different in the SUMMER. Feed efficiency was not affected by WDGS level or time of year. Nitrogen and P intake increased linearly with WDGS inclusion in both the SUMMER and WINTER. An increase in N retention was observed in the WINTER as a result of the ADG response, but N retention was not different in the SUMMER. Nitrogen excretion increased linearly with WDGS inclusion, but the amount of N removed in the manure was not different in the WINTER but did increase linearly with WDGS level in the SUMMER. When expressed as a percentage of N excretion, N loss was not different in the WINTER or the SUMMER.

Summary

Barley can be grown under a variety of conditions making it an ideal cereal grain in western Canada and the Pacific Northwest. Processing of barley has been shown to have positive impacts on feedlot performance because processing disrupts the fibrous hull

that encapsulates the grain. Barley has a greater starch content and different digestion characteristics than corn, and thus may increase the risk of acidosis. Inclusion of DDGS in barley based diets may mitigate the increased risk of acidosis because the by product contains <5% starch on a DM basis as a result of the ethanol process. The process removes starch, and subsequently concentrates all other nutrients three-fold and generates a useful feedstuff. Feeding DDGS to cattle improves feedlot performance with optimal levels determined at 20 or 24% of diet DM.

Including monensin in high grain diets may also reduce the risk of digestive and metabolic disease. Feed efficiency response to monensin is variable, although improvements are commonly observed. Small differences in ADG and DMI in favor of feeding monensin have also been observed.

Feedlot manure contains a variety of nutrients and can be used to restore OM to depleted soil, thus providing an outlet for manure from the feedlot and a less expensive source of nutrients for crop production. Nitrogen is a valuable nutrient in cropping systems, and because N is likely to volatilize, minimizing N losses from the feedlot represents a challenge. Several methods to reduce N losses have been evaluated previously including altering the C:N ratio of the manure, using feed additives, increasing frequency of pen cleaning, and combinations of dietary manipulation and frequency of pen cleaning. Feeding DDGS alters manure characteristics as a result of the increased nutrient content of DDGS compared to the original grain. Due to differences in ambient temperature in winter and summer, N losses can vary between seasons.

Objectives

The objectives of this research were to 1) to determine if NIRS could accurately predict the feeding value of barley fed to cattle raised in a commercial feedlot setting, 2) evaluate the impact of high or low starch:NDF barley and 0% or 20% DDGS on feedlot performance, carcass characteristics, and N and P mass balance in commercial sized pens, and 3) evaluate the impact of high or low starch:NDF barley and 25 or 48 mg/kg monensin on feedlot performance, carcass characteristics, and N and P mass balance in commercial sized pens.

References

- Adams, J.R., Farran, T.B., Erickson, G.E., Klopfenstein, T.K., Macken, C.N., and C.B. Wilson. 2004. Effect of organic matter addition to the pen surface and pen cleaning frequency on nitrogen mass balance in open feedlots. J. Anim. Sci. 82:2153-2163.
- Anderson, V.L., Ilse, B.R., and R. Wiederholt. 2011. Effects of increasing levels of distillers grains in barley-based diets on growing and finishing feedlot performance, carcass traits, and nutrients in manure. Prof. Anim. Sci. 27: 547-552.
- ASAE, 2005. Manure production and characteristics. American Society of Agricultural and Biological Engineers. St Joseph, MI.
- Beauchemin, K.A., Jones, S.D.M., Rode, L.M., and V.J.H. Sewalt. 1997. Effects of fibrolytic enzymes in corn or barley diets on performance and carcass characteristics of feedlot cattle. Can J. Anim. Sci. 77:646-653.
- Berry, B.A., Krehbiel. C.R., Confer, A.W., Gill, D.R., Smith, R.A., and M. Montelongo. 2004. Effects of dietary energy and starch concentrations for newly received feedlot calves: I. Growth performance and health. J. Anim. Sci. 82:837-844.
- Beauchemin, K.A., McAllister, T.A., Dong, Y., Farr, B.I., and K.-J. Cheng. 1994. Effects of mastication on digestion of whole cereal grains by cattle. J. Anim. Sci. 72:236-246.
- Benson, C.S., C.L. Wright, K.E. Tjardes, R.E. Nicolai, and B.D. Rops. 2005. Effects of Feeding Varying Concentrations of Dry Distiller's Grains with Solubles on Finishing Steers on Feedlot Performance, Nutrient Management and Odorant Emissions. South Dakota Beef Report. pp. 59-67.
- Bhatty, R.S., Berdahl, J.D., and G.I. Christison. 1975. Chemical composition and digestible energy of barley. Can. J. Anim. Sci. 55: 759-764.
- Bhatty, R.S., Christison, G.I., Sosulski, F.W., Harvey, B.L., Hughes, G.R., and J.D. Berhahl. 1974. Relationships of various physical and chemical characters to digestible energy in wheat and barley cultivars. Can. J. Anim. Sci. 54:419-427.
- Bierman, S., Erickson, G.E., Klopfenstein, T.K., Stock, R.A., Shain, D.H. 1999. Evaluation of nitrogen and organic matter balance in the feedlot as affected by level and source of dietary fiber. J. Anim. Sci. 77:1645-1653.
- Bierman, S., T. Klopfenstein, R. Stock, and D. Shain. 1996. Evaluation of nitrogen, phosphorus, and organic matter balance in the feedlot as affected by nutrition. Nebraska Beef Cattle Rep. MP 67-A. 74-77.
- Bierman, S., Erickson, G.E., Klopfenstein, T.K., Stock, R.A., Shain, D.H. 1999. Evaluation of nitrogen and organic matter balance in the feedlot as affected by level and source of dietary fiber. J. Anim. Sci. 77:1645-1653.

- Boling, J. A., Bradley, N. W., and L. D. Campbell. 1977. Monensin levels for growing and finishing steers. J. Anim. Sci. 44:867-871.
- Boss, D. L., and J. G. P. Bowman. 1996. Barley varieties for finishing steers: I. Feedlot performance, in vivo diet digestion, and carcass characteristics. J. Anim. Sci. 74:1967-1972.
- Bowman, J. G. P., T. K. Blake, L. M. M. Surber, D. K. Habernicht, and H. Bockelman. 2001. Feed-quality variation in the barley core collection of the USDA national small grains collection. Crop. Sci. 41:863-870.
- Bremer, V.R., Watson, A.K., Liska, A.J., Erickson, G.E., Cassman, K.G., Hanford, K.J., and T.J. Klopfenstein. 2011. Effect of distillers grains moisture and inclusion level in livestock diets on greenhouse gas emissions in the corn-ethanol-livestock life cycle. Prof. An. Sci. 27:449-455.
- Bremer, V.R., Buckner, C.D., Erickson, G.E., and T.J. Klopfenstein. 2008. Total and water soluble phosphorus content of feedlot cattle feces and manure. Nebraska Beef Cattle Report. MP 91: 69-70.
- Buckner, C.D., Bremer, V.R., Klopfenstein, T.J., Erickson, G.E., Vander Pol, K.J., Karges, K.K., and M.L. Gibson. 2011a. Evaluation of a prefermentation-fractionated byproduct corn grain dry milling ethanol process in growing and finishing cattle diets. Prof. An. Sci. 27:295-301.
- Buckner, C.D., Wilken, M.F., Benton, J.R., Bremer, V.R., Klopfenstein, T.J., Kononoff, P.J., and G.E. Erickson.2011b. Nutrient variability for distillers grains plus solubles and dry matter determination of ethanol byproducts. Prof Anim Sci. 27:57-64.
- Buckner, C.D., Mader, T.L., Erickson, G.E., Colgan, S.L., Mark, D.R., Bremer, V.R., Karges, K.K., and M.L. Gibson. 2008. Evaluation of dry distillers grains plus solubles inclusion on performance and economics of finishing beef steers. Prof. Anim. Sci. 24:404-410.
- Buckner, C.D., G.E. Erickson, T.J. Klopfenstein, R.A. Stock, and K.J. Vander Pol. 2007. Effect of feeding a byproduct combination at two levels or byproduct alone in feedlot diets. 2007 Nebraska Beef Cattle Report. MP 90. 25-26.
- Burrin, D. G., and R. A. Britton. 1986. Response to monensin in cattle during sub acute acidosis. J. Anim. Sci. 63:888–893.
- Burrin, D. G., R. A. Stock, and R. A. Britton. 1988. Monensin level during grain adaptation and finishing performance in cattle. J. Anim. Sci. 66:513–521.
- Canadian Grain Commission, 2010. Available at http://www.grainscanada.gc.ca/barley-orge/harvest-recolte/2010/qbsm10-qosm10-eng.pdf
- Carpenter, L. E. 1970. Nutrient composition of distillers feeds. In: Proc. Distillers Feed Res. Council, Cincinnati, OH. 25:54–61.

- Cooper, R.J., Klopfenstein, T.J., Stock, R.A., Milton, C.T., Herold D.W., and J C Parrott. 1999. Effects of imposed feed intake variation on acidosis and performance of finishing steers. J. Anim. Sci. 77:1093-1099.
- Cooper, R.J., Klopfenstein, T.J., Stock, R.A., Parrott, C., and D. Herold. 1997. Effect of Rumensin and feed intake variation on ruminal pH. Nebraska Beef Cattle Report. MP 67-A. 49-52.
- Depenbusch, B. E., Coleman, C. M., Higgins, J. J., and J. S. Drouillard. 2009. Effects of increasing levels of dried corn distillers grains with solubles on growth performance, carcass characteristics, and meat quality of yearling heifers. J. Anim. Sci. 87: 2653-2663.
- Dew, D.A. and V.M. Bendelow. 1963. The effect of swathing at different stages of maturity on the malting quality of barley. Can. J. Plant. Sci. 43: 534-541.
- Dinius, D. A., M. E. Simpson and P. B. Marsh. 1976. Effect of monensin fed with forage on digestion and the ruminal ecosystem of steers. J. Anim. Sci. 42:229-234.
- Doerr, A.J., Nuttelman, B.L., Griffin, W.A., Erickson, G.E., Klopfenstein, T.J., Benton, J.R., and M.J. Rincker. 2012. Effect on Performance and Nutrient Mass Balance of Feeding Micro-Aid in Wet Distillers Grains Plus Solubles Diets. Nebraska Beef Cattle Report. MP 95-A:98-100.
- Edney, M.J., Morgan, J.E., Williams, P.C., and L.D. Campbell. 1994. Analysis of feed barley by near infrared reflectance technology. J. Near Infrared Spectrosc. 2:33-41.
- Engstrom, D.F., G.W. Mathison, and L.A. Goonewardene. 1992. Effect of β-glucan, starch, and fibre content and steam vs. dry rolling of barley grain on its degradability and utilization by steers. Anim. Feed Sci. Tech. 37:33-46.
- Erickson, G.E. and T.J. Klopfenstein. 2010. Nutritional and management methods to reduce nitrogen losses from beef feedlots. J. Anim. Sci. 88:E172-E180.
- Erickson, G. E., and T. J. Klopfenstein. 2001. Nutritional methods to decrease N losses from open-dirt feedlots in Nebraska. The Scientific World Journal 1(Suppl. S2):836-843.
- Erickson, G.E., Milton, C.T., Fanning, K.C., Cooper, R.J., Swingle, R.S., Parrott, J.C., Vogel, G., and T.J. Klopfenstein. 2003. Interaction between bunk management and monensin concentration on finishing performance, feeding behavior, and ruminal metabolism during an acidosis challenge with feedlot cattle. J. Anim. Sci. 81:2869-2879.
- Erickson, G.E., Klopfenstein, T.J., and T. Milton. 2002. Corn bran level in finishing diets and N losses from open-dirt pens. Nebraska Beef Report, MP 79a: 54-57
- Erickson, G., and T. Klopfenstein. 2002. Distillers grains for beef cattle. Proc. North Central Distillers Grains Conf., Prior Lake, MN.

- Erickson, G.E., Klopfenstein, T.J., Milton, T., and D. Walters. 2000. Dietary phosphorus effects on waste management and nutrient balance in the feedlot. Nebraska Beef Cattle Report. MP 73-A:65-67.
- Eun, J.S., ZoBell, D. R., and Wiedmeier, R. D. 2009. Influence of replacing barley grain with corn-based dried distillers grains with solubles on production and carcass characteristics of growing and finishing beef steers. Anim. Feed Sci. Technol. 152: 72-80.
- Farran, T. B., Erickson, G. E., Klopfenstein, T. J., Macken, C. N., and R. U. Lindquist. 2003. Wet corn gluten feed and alfalfa hay levels in dry-rolled corn finishing diets: Effects on finishing performance and feedlot nitrogen mass balance. J. Anim. Sci. 2006. 84:1205-1214.
- Fife, T.E., Szasz, J. I., Hunt, C. W. and J. A. Ahola. 2008. Relationship between quality characteristics of barley grain and digestibility in feedlot steers. Prof. Anim. Sci. 24: 560-565.
- Fulton, W. R., Klopfenstein, T. J., and R. A. Britton. 1979. Adaptation to high concentrate diets by beef cattle. 1. Adaptation to corn and wheat diets. J. Anim. Sci. 49:775–784.
- Galyean, M. L., Malcolm, K. J. and Duff, G. C. 1992. Performance of feedlot steers fed diets containing laidlomycin propionate or monensin plus tylosin, and effects of laidlomycin propionate concentration on intake patterns and ruminal fermentation in beef steers during adaptation to a high concentrate diet. J. Anim. Sci. 70: 2950-2958.
- Galyean, M. L. and Rivera, J. D. 2003. Nutritionally related disorders affecting feedlot cattle. Can. J. Anim. Sci. 83: 13-20.
- Gibb, D. J., X. Hao, and T. A. McAllister. 2008. Effect of dried distillers' grain from wheat on diet digestibility and performance in feedlot cattle. Can. J. Anim. Sci. 88: 659-665.
- Gibb, D.J., Streeter, M., Schwartzkopf-Genswein, K.S., and T.A. McAllister. 2008. Performance and bunk attendance of cattle fed steamrolled or ground corn supplemented with laidlomycin and chlortetracycline or monensin and tylosin. Can. J. Anim. Sci. 88:499-506.
- Goodrich, R. D., Garrett, J. E., Gast, D. R., Kirick, M. A., Larson, D. A., and J. C. Meiske. 1984. Influence of monensin on the performance of cattle. J. Anim. Sci. 58:1484–1498.
- Haney, M. E., Jr. and M. M. Hoehn. 1967. Monensin, a new biologically active compound. Antimicrob. Agents and Chemothe. 349-352.
- Ham, G. A., R. A. Stock, T. J. Klopfenstein, E. M. Larson, D. H. Shain, and R. P. Huffman. 1994. Wet corn distillers byproducts compared with dried corn distillers with solubles as a source of protein and energy for ruminants. J. Anim. Sci. 72: 3246-3257.

- Harrold, R.L. and M.E. Kapphahn. 1997. Nutritional Analysis, Regional Barley Crop Quality Report. North Dakota Barley Council, Minnesota Barley Research and Promotion Council and North Dakota State University.
- Hinman, D. D. 1979. A comparison of malting vs. feed barley varieties on beef cattle performance. Proc. West. Sect. Am. Soc. Anim. Sci. 30: 49–51.
- Hinman, D.D. and J.J. Combs. 1983. Tempered versus dry-rolled barley rations for feedlot steers. Proc. West. Sec. Amer. Soc. Anim. Sci. 34:306-307.
- Hinman, D.D. and J.J. Combs. 1984. Performance of steers fed either dry-rolled, temper-rolled, or steam-rolled barley based grower and finishing rations. Proc. West. Sec. Amer. Soc. Anim. Sci. 35:246-248.
- Hutchinson, G. L., Mosier, A. R., and C. E. Andre. 1982. Ammonia and amine volatilization from a large cattle feedlot. J. Environ. Qual. 11:288-293.
- Kemalyan, R. K., Petersen, M. K., Newman, C. W., Clark, C. K., Roth, N. J., Thomas, V. M. and McGuire, C. 1990. Effect of barley cultivar on digestive responses in mature rambouillet ewes. Proc. West. Sec. Am. Soc. Anim. Sci. 41: 415–417.
- Kim, H.O. and Williams, P.C. 1990. Determination of starch and energy in feed grains by near infrared reflectance spectroscopy. J. Agric. Food Chem. 38:682–688
- Kirk, D. J., L. W. Greene, G. T. Schelling, and F. M. Byers. 1985. Effects of monensin on Mg, Ca, P and Zn metabolism and tissue concentrations in lambs. J. Anim. Sci. 60:1485-1490.
- Kissinger, W.F., Koelsch, R.K., Erickson, G.E., and T.J. Klopfenstein. 2007. Characteristics of manure harvested from beef cattle feedlots. Appl. Eng. Agric. 23: 357-365
- Kissinger, W.F., Erickson, G.E., Klopfenstein, T.J., and R.K. Koelsch. 2006. Managing phosphorus in beef feedlot operations. Nebraska Beef Cattle Report. MP 88-A. 94-97.
- Klopfenstein, T. J., G. E. Erickson, and V. R. Bremer. 2008. Board-invited Review: Use of distiller byproducts in the beef cattle feeding industry. J. Anim. Sci. 86: 1223-1231
- Klopfenstein, T., J. Waller, N. Merchen, and L. Petersen. 1978. Distillers grains as a naturally protected protein for ruminants. Distillers Feed Conference Proceedings 33:38–46.
- Lory, J., Adams, J., Eghball, B., Klopfenstein, T. and J. Powers. 2002. Effect of sawdust or acid application to pen surfaces on nitrogen losses from open-dirt feedlots. Neb. Beef Cattle Rep. MP 79-A:52–53.
- Loy, D.D., D.R. Strohbehn, and R.E. Martin. 2005. Factors Affecting the Economics of CornCo-Products in Cattle Feeds. Ethanol Co-Products for Cattle. Iowa State University Extension. IBC-28, August.

- Luebbe, M.K., Erickson, G.E., Klopfenstein, T.K., and M.A. Greenquist. 2012. Nutrient mass balance and performance of feedlot cattle fed corn wet distillers grains plus solubles. J. Anim. Sci. 90:296-306.
- Luebbe, M.K., Erickson, G.E., Klopfenstein, T.K., Greenquist, M.A., and J.R. Benton. 2009. Effect of dietary cation-anion difference on feedlot performance, nitrogen mass balance and manure pH in open feedlot pens. Nebraska Beef Cattle Report. MP 92. 91-93.
- Luebbe, M.K., Erickson, G.E., Klopfenstein, T.K., and M.A. Greenquist. 2008. Nutrient mass balance and performance of feedlot cattle fed corn wet distillers grains plus solubles. Nebraska Beef Cattle Report. MP 91. 60-62.
- Mateo, K.S., Tjardes, K.E., Wright, C.L., Koger, T.J., and B.D. Rops. 2004. Evaluation of Feeding Varying Levels of Wet Distillers Grains with Solubles as Compared to Dry Distillers Grains with Solubles to Finishing Steers. 2004 South Dakota Beef Report. pp. 14-19.
- Mathison, G.W., Engstrom, D.F., and D.D. Macleod. 1991a. Effect of feeding whole and rolled barley to steers in the morning or afternoon in diets containing differing proportions of hay and grain. Anim. Prod. 53:321-330.
- Mateo, K.S., Tjardes, K.E., Wright, C.L., Koger, T.J., and B.D. Rops. 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 Rep. 2004–03: 14-19.
- McDonnell, M.F., Bowman, J.G.P., and C.W. Labbe. 2004. Effects of barley cultivar and growing environment on feedlot performance and carcass characteristics of finishing beef cattle. Proc. West. Sect. Am. Soc. Anim. Sci. 55:53-56.
- Morse, D., H.H. Head, C.J. Wilcox, H.H. Van Horn, C.D. Hissem, and B. Harris, Jr.1992. Effects of Concentration of Dietary Phosphorus on Amount and Route of Excretion. J. Dairy. Sci. 75:3039-3049.
- Miller, K. A, M. K. Shelor, G. L. Parsons, and J. S. Drouillard. 2009. Optimal roughage level in finishing diets containing combinations of flaked corn and dried distiller's grains with solubles. J. Anim. Sci. 87(E-Suppl.):191 (Abstr.).
- Miller, M. C. 1992. Nutrient composition of Pacific Northwest barley and effect of starch type and β-glucan and fiber levels on its energy content for poultry and swine. Master's thesis. Washington State University, Pullman, WA.
- National Research Council, Nutrient Requirements for Beef Cattle, 7th Revised Edition, National Academy Press, Washington DC.
- Nagaraja, T. G., Avery, T. B., Bartley, E. E., Galitzer, S. J., and A. D. Dayton. 1981. Prevention of lactic acidosis in cattle by lasalocid or monensin. J. Anim. Sci. 53:206–216.

- Nagaraja, T. G., Avery, T. B., Bartley, E. E., Roof, S. K., and A. D. Dayton. 1982. Effect of lasalocid, monensin or thiopeptin on lactic acidosis in cattle. J. Anim. Sci. 54:649-658.
- Olentine, C. 1986. Ingredient profile: distillers feeds. In: Proc. Distillers Feed Conf., Cincinatti, OH. 41:13–24.
- Ovenell-Roy, K.H., Nelson, M.L., Froseth, J.A., Parish, S.M., and E.L. Martin. 1998. Variation in chemical composition and nutritional quality among barley cultivars for ruminants. 1. Steer finishing performance, diet digestibilities and carcass characteristics. Can. J. Anim. Sci. 78:369-375.
- Ovenell, K. H., M. L. Nelson, J. A. Froseth, S. M. Parish, and E. L. Martin. 1993. Feedlot performance, carcass characteristics of steers, and digestibility of diets containing different barley cultivars. Proc. West. Sect. Am. Soc. Anim. Sci. 44:416.
- Owens, F.N., Secrist, D.S., Hill, W.J., and D.R. Gill. 1998. Acidosis in cattle: a review. J. Anim. Sci. 76: 275-286.
- Owens, F. N., D. S. Secrist, W. J. Hill, and D. R. Gill. 1997. The effect of grain source and grain processing on the performance of feedlot cattle: A review. J. Anim. Sci. 75:868–879.
- Perry, T. W., Beeson, W. M., and M. T. Mohler. 1976. Effect of monensin on beef cattle performance. J. Anim. Sci. 42:761-765.
- Potter, E. L., Cooley, C. O., Raun, A. P., Richardson, L. F., and R. P. Rathmacher. 1974. Effect of monensin on daily gain of cattle on pasture. J. Anim. Sci. 38:1344- (Abstr.).
- Pressman, B. C. 1976. Biological applications of ionophores. Annu. Rev. Biochem. 45:501-530.
- Quinn, S.A., Erickson, G.E., Klopfenstein, T.J., Stowell, R.R., and D.M. Sherwood. 2007. Effect of phase feeding protein on cattle performance and nitrogen mass balance in open feedlots. Nebraska Beef Cattle Report. 52-54.
- Raun, A.P., Cooley, C.O., Potter, E.L., Rathmacher, R.P., and L.F. Richardson. 1976. Effect of monensin on feed efficiency of feedlot cattle. J. Anim. Sci. 43:670-677.
- Reynolds, W. K., C. W. Hunt, J. W. Eckert, and M. H. Hall. 1992. Evaluation of the feeding value of barley as affected by variety and location using near infrared reflectance spectroscopy. Proc. West. Sec. Amer. Soc. Anim. Sci. 43:498-501.
- Rich, A.R., Erickson, G.E., Klopfenstein, T.J., Luebbe, M.K., Benton, J.R., and W.A. Griffin. 2011. Effect of pen cleaning frequency and feeding distillers grains and wheat straw on nutrient mass balance and performance of feedlot steers. Nebraska Beef Cattle Report. 84-86.
- Richardson, L. F., A. P. Raun, E. L. Potter, C. O. Cooley, and R. P. Rathmacher. 1976. Effect of monensin on rumen fermentation in vitro and in vivo. J. Anim. Sci. 43:657–664.

- Sayer, K.M., Erickson, G.E., Klopfenstein, T.J., Vander Pol, K.J., and C.N. Macken. 2005. Effects of corn bran and corn steep inclusion in finishing diets on cattle performance and nitrogen mass balance. Nebraska Beef Cattle Report. 54-56.
- Smith, J. B. and E. Rozengurt. 1978. Serum stimulates the Na, K-pump in quiescent fibroblasts by increasing Na entry. Proc. Natl. Acad. Sci. USA75:5560.
- Spears, J. W. 1990. Ionophores and nutrient digestion and absorption in ruminants. J. Nutr. 120:632-638.
- Speihs, M. J., M. H. Whitney, and G.C. Shurson. 2002. Nutrient database for distiller's dried grains with solubles produced from new ethanol plants in Minnesota and South Dakota. J. Anim. Sci. 80: 2639-2645.
- Sanford, B.J., Grove, A.V., and C. W. Hunt. 2003. Evaluation of barley characteristics that are associated with digestible energy for beef cattle. Prof. Anim. Sci. 19:281-285.
- Starnes, S. R., Spears, J.W., Froetschel. M.A., and W. J. Croom, Jr. 1984. Influence of monensin and lasalocid on mineral metabolism and ruminal urease activity in steers. J. Nutr. 114:518-525.
- Stock, R. A., J. M. Lewis, T. J. Klopfenstein, and C. T. Milton. 2000. Review of new information on the use of wet and dry milling feed byproducts in feedlot diets. J. Anim. Sci. http://www.asas.org/symposia/proceedings/0924.pdf. Accessed February 20, 2012.
- Stock, R. A., S. B. Laudert, W. W. Stroup, E. M. Larson, J. C. Parrott, and R. A. Britton. 1995. Effects of monensin and monensin and tylosin combinations on feed intake variation of feedlot steers. J. Anim. Sci. 73:39–44.
- Stock, R. A., and R. A. Britton. 1993. Acidosis in feedlot cattle. In: Scientific Update on Rumensin/Tylan for the Professional Feedlot Consultant. Elanco Animal Health, Indianapolis, IN.
- Stock, R.A., Sindt, M.H., Parrot, J.C., and F.K. Goedeken. 1990. Effects of grain type, roughage level and monensin level on finishing cattle performance. J. Anim. Sci. 68:3441-3455.
- Surber, L.M. and J. G. Bowman. 1998. Monensin effects on digestion of corn or barley high-concentrate diets. J. Anim. Sci. 76:1945-1954.
- Taylor, P. 1985. The nutritional value of barley for growing swine and finishing steers. Master's thesis. Washington State University, Pullman, WA.
- Tjardes, K. and C. Wright. 2002. Feeding Corn Distiller's Co-Products to Beef Cattle. South Dakota State University Cooperative Extension Service. Ex 2036, August.
- Theurer, C.R. 1986. Grain processing effects on starch utilization by ruminants. J. Anim. Sci. 63:1649-1662.

- Toland, P.C. 1976. The digestibility of wheat, barley or oat grain fed either whole or rolled at restricted levels with hay to steers. Aust. J. Exp. Agric. and Anim. Husb. 16:71-75.
- Tomlinson, A.P., W.J. Powers, H.H. Van Horn, R.A. Nordstedt, and C.J. Wilcox. 1996. Dietary Protein Effects on Nitrogen Excretion and Manure Characteristics of Lactating Cows. Trans. of the ASAE. 39:1441-1448.
- Utley, P. R., Newton, G. L., Ritter III, R. J., and W. C. McCormick. 1976. Effects of feeding monensin in combination with zeranol and testosterone-estradiol implants for growing and finishing heifers. J. Anim. Sci. 42:754-760.
- Vander Pol, K.J., Luebbe, M.K., Crawford, G.I., Erickson, G.E., and T.J. Kopfenstein. 2009. Performance and digestibility characteristics of finishing diets containing distillers grains, composites of corn processing coproducts, or supplemental corn oil. J. Anim. Sci. 87:639-652.
- Vasconcelos, J.T. and M.L. Galyean. 2007. Nutritional recommendations of feedlot consulting nutritionists: The 2007 Texas Tech University survey. J. Anim. Sci. 85:2772-2781.
- Vasconcelos, J.T., Tedesci, L.O., Fox, D.G., Galyean, M.L., and L.W. Greene. 2007. Review: feeding nitrogen and phosphorus in beef cattle production to mitigate environmental impacts. Prof. Anim. Sci. 23:8-17.
- Waldo, D. R. 1973. Extent and partition of cereal grain starch digestion in ruminants. J. Anim. Sci. 37: 1062–1074.
- Walter, L. J., J. L. Aalhus, W. M. Robertson, T. A. McAllister, D. J. Gibb, M. E. R. Dugan, N. Aldai and J. J. McKinnon. 2010. Evaluation of wheat or corn distillers' grains with solubles on performance and carcass characteristics of feedlot steers. Can. J. Anim. Sci. 90: 259-269.
- Wang, Y., Greer, D., and T.A. McAllister. 2003. Effects of moisture, roller setting, and saponin-based surfactant on barley processing, ruminal degradation of barley, and growth performance by feedlot steers. J. Anim. Sci. 81: 2145-2154.
- Waterbury, J. A. and D. R. Mark. 2008. Ethanol byproduct prices. Cornhusker Economics. University of Nebraska-Lincoln Extensio
- Williams, P.C., Preston, K.R., Norris, K.H., and P.M. Starkey. 1984. Determination of Amino Acids in Wheat and Barley by Near-Infrared Reflectance Spectroscopy. J. Food. Sci. 49:17-20.
- Zinn, R. A., Plascencia, A., and R. Barajas. 1994. Interaction of forage level and monensin in diets for feedlot cattle on growth performance and digestive function. J. Anim. Sci. 72:2209-2215.

CHAPTER II: EVALUATION OF THE EFFECTS OF FEEDING HIGH AND LOW ENERGY BARLEY ON FEEDLOT CATTLE PERFORMANCE IN WESTERN CANADA

E. M. Hussey*[‡], G.E. Erickson*, R.E. Peterson[‡], L.O. Burciaga-Robles[‡], and M.L. May[‡]

*Department of Animal Science, University of Nebraska, Lincoln 68583, [‡]Feedlot Health

Management Services Ltd., Okotoks, AB, Canada T1S 2A2

Abstract

Crossbred heifer calves (n=9,007, 30 pens, 272 ± 34 kg blocked by initial BW) were assigned randomly at feedlot arrival to one of three experimental groups to determine if Near Infrared Spectroscopy (NIRS) could accurately segregate barley based on feeding value when fed to cattle in a commercial feedlot setting. The three treatments included a group fed low digestible energy (DE, LOW), a group fed barley high in DE (HIGH), and a group fed a blend of high and low DE barley (50:50). For each load of barley, crude protein, fat, DM, acid detergent fiber (ADF), neutral detergent fiber (NDF), crude fiber, ash, and net energy (NE) were measured by NIRS. From those measurements, other calculations were made to estimate the DE using NRC (1996) equations. On a live weight basis, final BW, weight gain, ADG, and G:F were not different (P≥0.11). On a carcass-adjusted basis, final BW, ADG, and G:F were not different ($P \ge 0.10$). Treatment differences and a small linear decrease (P < 0.01) on DMI was observed as the DE of the diet increased (LOW 8.3 kg; 50:50 8.3 kg; HIGH 8.2 kg). Carcass weight, 12th rib fat, LM area, marbling score, and dressing percentage were not impacted by treatment ($P \ge 0.39$). No differences ($P \ge 0.46$) in the percentage of carcasses

grading choice, select, or standard were observed. However, there was a linear increase (P=0.05) in the percentage of carcasses grading prime as DE increased. No differences $(P\ge0.18)$ in the percentage of animals pulled for respiratory disease were observed. Similarly, there were no differences $(P\ge0.12)$ in the percentage of animals that died as a result of respiratory disease or lameness. Treatment differences (P=0.02) and a quadratic relationship was observed for metabolic mortality (LOW 0.53%, 50:50 1.10%, HIGH 0.90%, P=0.02). Treatment differences (P=0.04) and a quadratic relationship was observed for overall mortality (LOW 1.96%, 50:50 3.10%, HIGH 3.00%, P<0.01). Feeding LOW barley increased weight gain, DMI, and mortality compared to HIGH; with little effect on carcass composition.

Key words: barley, digestible energy, feedlot cattle, NIRS

Introduction

Feed cost of gain accounts for 65-80% of the total cost of production and understanding the nutrient profile of the feed consumed by animals is important to investigate. Barley (*Hordeum vulgare* L.) has traditionally been the primary grain used in feedlot rations in western Canada and the Pacific Northwest as an energy and protein source. The nutrient content compares favorably with that of corn, oats, wheat, and milo (NRC, 1996). The crude protein content of barley is higher than corn and the energy content (TDN, NEm, NEg) of barley is slightly lower than corn due higher fiber content (NRC, 1996). Currently most feedlots procure barley based on physical attributes such as plumpness, bushel weight, and moisture. Based on these physical characteristics, some feedlots have pricing mechanisms set in place for barley that does not meet site

specifications. These pricing mechanisms may or may not correlate with the feeding value and animal performance in the feedlot. Nutrient composition is variable and may be affected by geographical location, growing conditions, year of production, two-row or six-row, feed or malting type, and season planted (Taylor, 1985; Kemalyan et al. 1990; Miller, 1992). In addition, there is considerable variability in nutritive value among barley varieties (Reynolds et al., 1992; Bowman et al., 2001), which can lead to differences in animal performance (Hinman 1979). Feeding value of barley can potentially be evaluated real-time using near infrared spectroscopy (NIRS) with calibration models correlated to specific wet chemistry parameters. A feeding trial was conducted to evaluate segregating barley by its estimated digestible energy value using NIRS.

The objective of this study was to determine if NIRS could segregate barley based on estimated DE content and impact health, performance, and carcass characteristics.

Materials and Methods

All procedures involving live animals were approved by the Feedlot Health

Management Services Ltd. (FHMS) Animal Care and Use Committee with informed

consent from the animal owners.

Study Facilities

The study was conducted at a Western Feedlots Ltd.- High River, a commercial feedlot near High River, AB, Canada. The cattle were housed in standard facilities for western Canada including open-air, dirt-floor pens with central feed alleys and 20% porosity wood-fence windbreaks. Animal handling facilities had a hydraulic chute

equipped with an individual animal scale, a chute-side computer with individual animal data collection, management software (*i*FHMS, Feedlot Health Management Services Ltd., Okotoks, AB, Canada) and separation alleys to facilitate the return of animals to designated pens.

Barley Attributes

A NIRS instrument (InfraXact NIRS, FOSS North America, Eden Prairie, MN) was purchased and barley was scanned using NIRS. The protocol for calibration development is proprietary information, property of Western Feedlots Ltd.

Once an adequate NIRS calibration was developed, barley was segregated for the feeding experiment to evaluate if NIRS could accurately predict the feeding value of barley fed to cattle raised in a commercial feedlot setting. Barley delivered to the feedlot was sampled from each load delivered by truck, immediately scanned with NIRS. For each load of barley, crude protein, ether extract, DM, acid detergent fiber (ADF), neutral detergent fiber (NDF), crude fiber, ash, and net energy (NE) were measured. From those measurements, calculations can be made to estimate the DE using NRC (1996) equations. Digestible energy was the parameter used to separate the barley into three quality categories: low energy barley (LOW), high energy barley (HIGH), and a 50:50 blend of the high and low energy barley (50:50). Once a shipment of barley was determined to be HIGH or LOW, it was stored by barley treatment, tempered to 18.5% moisture and rolled. A surfactant (Grain Prep Processing Aid, Agri Chem, Inc., Ham Lake, MN) was also added to the barley. The 50:50 blend was generates by mixing equal amounts of high and low energy barley in the feed truck.

Study Animals

At the time of feedlot arrival, each animal was individually weighed (Model LS51208, Cardinal Scale Manufacturing Co. Webb City, MO) and received health and production products as per standardized commercial feedlot practices which included individual animal identification, an infectious bovine rhinotracheitis (IBR) virus, parainfluenza-3 (PI₃) virus, bovine viral diarrhea (BVD) virus (types I and II) and bovine respiratory syncytial virus combination vaccine (Bovi-Shield[®] Gold 5, Pfizer Animal Health, Kirkland, QC), a Mannheimia haemolytica toxoid (Presponse® SQ, Boehringer Ingelheim Animal Health, Boehringer Ingelheim Canada Ltd., Burlington, ON), a Clostridium chauvoei, septicum, novyi, sordellii, perfringens Types B, C and D and Histophilus somni bacterin-toxoid (Ultrabac 7/Somubac[®], Pfizer Animal Health), topical doramectin for gastrointestinal and external parasite control (Dectomax[®] Pour-On Solution, Pfizer Animal Health (1 mL/10 kg)), an intramuscular (IM) prostaglandin for termination of pregnancy (Lutalyse[®], Pfizer Animal Health), and IM long-acting oxytetracycline (Oxymycine LA 300, Wyeth Animal Health, Division of Wyeth Canada, Guelph, ON). Weight and hip height were recorded for each animal and each animal was given a numbered visual identification tag. After treatment assignment, all heifers were rehandled at approximately 45 and 132 days on feed for reimplant and revaccination. At 45 days on feed heifers received a Synovex Choice[®] implant (Pfizer Animal Health), and an infectious bovine rhinotracheitis (IBR) virus, parainfluenza-3 (PI₃) virus, bovine viral diarrhea (BVD) virus (types I and II), and bovine respiratory syncytial virus combination vaccine (Bovi-Shield® Gold 5, Pfizer Animal Health). At approximately 132 days on feed heifers received a Synovex Choice[®] implant (Pfizer Animal Health), and an

infectious bovine rhinotracheitis (IBR) virus vaccine (Pyramid IBR, Boehringer Ingelheim Animal Health).

Experimental Design

At the time of feedlot arrival, crossbred heifer calves (n=9,007, 272 ± 34 kg initial BW) were individually assigned randomly to one of three treatments from December 2008 to September 2009 based on a computer generated randomization table. The three experimental groups were: LOW (diets contained barley that was determined to be low in digestible energy), HIGH (diets contained barley that was determined to be high in digestible energy), or 50:50 barley (diets contained a 50:50 blend of high and low barley). Study animals were housed by experimental group in commercial feedlot pens and followed from allocation until slaughter.

Complete feedlot diets and water were offered *ad libitum* throughout the feeding period. Feedlot diets were blended in truck-mounted mixer boxes (Cattlelac, Reg Cox Feed Mixers Inc., Red Deer, AB Canada) equipped with electronic load cells. Diets were delivered to the pens once daily at 0700 and daily feed allowances to each pen were recorded using the feedlot administrative software (Feedback, ComputerAid Professional Services Ltd., Okotoks, AB). Rations and ration changes associated with step up to the finishing diet were based on commercial feedlot protocols, and occurred on the same day within each replicate. Animals received pulse dose feeding regimes of CTC in accordance with the standard CTC feeding program for the control of *Histophilus somni* (HS) during the first part of the feeding period. A pulse was defined as five consecutive days of CTC (Aureomycin® 220 G, Alpharma Canada Corporation, Mississauga, ON) at a

dosage of 1 g CTC/45 kg BW/animal daily. Study animals were conditioned to a high concentrate diet composed of approximately 90.08% barley, 5% barley silage, 2% tallow, and 2.92% supplement on a DM basis over a 20 to 28 day period. Animals remained on the high concentrate diet until slaughter.

The supplement included in the ration was manufactured at a commercial feed mill (Landmark Feeds, Strathmore, AB). Monensin was included in the diet at 27.6 mg/kg DM (Rumensin, Elanco Animal Health, Indianapolis, Indiana), tylosin included at 12.1 mg/kg DM (Tylan, Elanco Animal Health), and melengestrol acetate was included at 0.5 mg/heifer daily (MGA, Pfizer Animal Health). Feedbunk samples were collected monthly. For each pen, equal sized feed samples were collected from the beginning, middle, and end of the bunk. On each sampling day, samples from each pen in an experimental group were composited to form one sample for each experimental group. Samples were frozen until the end of the study. Samples were submitted to a commercial lab (Benchmark Labs, Calgary, AB) for DM (AOAC 930.15) and CP (AOAC 954.01), acid detergent fiber (ADF) (Ankom Inc., 2006), calcium (Ca), and phosphorus (P) analysis (ICP-MS). For Ca and P, a representative 1 gram (dry weight) sample was digested with repeated additions of nitric acid (HNO₃) and hydrogen peroxide (H₂O₂). The resultant digestate was reduced in volume while heating and then diluted to a final volume of 50 mL. The digestate was then filtered, and the filter paper and residues are rinsed. The digestate was then diluted 10 times or more (if necessary) and analyzed on an HP 4500 ICP-MS (GMI Inc. Ramsey, MN).

Animal Health and Marketing

Experienced animal health personnel observed the study animals at least once daily for evidence of disease. Animals deemed to be "sick" by the animal health personnel, based on subjective criteria such as general appearance, attitude, gauntness, reluctance to move, etc., were individually sorted from pen mates, moved to the hospital facility, diagnosed, and treated according to the standard feedlot protocol. The treatment date, the presumptive diagnosis, drug(s) administered, and dose(s) used were recorded.

The case definition for undifferentiated fever (UF) was a lack of abnormal clinical signs referable to body systems other than the respiratory system, a rectal temperature ≥ 40.6°F, and no previous treatment history. The case definition for no fever (NF) was a lack of abnormal clinical signs referable to body systems other than the respiratory system, a rectal temperature < 40.6°F, and no previous treatment history for UF. Animals identified as "sick" subsequent to the third relapse therapy for each disease in the treatment protocol were deemed to be "chronics". Also, animals that were unsuitable to be returned to their designated feedlot pens, based on subjective appraisal of the attitude and appearance of each animal, were deemed to be "chronics". Chronics that did not die during the study were defined as wastage. Chronics and wastage were included in the performance calculations, described in Table 1.

A gross necropsy examination was performed on each animal that died during the study period by trained personnel from Feedlot Health Management Services Ltd. (FHMS). All animals that died were weighed by feedlot personnel. Animals that died as a result of bovine respiratory disease (BRD) were classified as BRD mortalities. Animals that died as a result of lesions consistent with *Histophilus somni* (HS) infection were

classified as HS mortalities. Animals that died as a result of lameness (arthritis, foot rot, or foot lesions) were classified as lameness mortalities, and animals that died as a result of metabolic disease (atypical interstitial pneumonia, bloat, chronic rumenitis, enterotoxemia, laminitis, liver abscesses, grain overload, or posterior vena cava thrombosis) were classified as metabolic mortalities. Animals that died of miscellaneous causes (causes other than BRD, HS, lameness, or metabolic disease) were classified as miscellaneous mortalities. Overall mortality is the sum of all mortalities throughout the study period. Weights and number of animals that died or were shipped for salvage slaughter during the study were accounted for in the performance calculations.

At the end of the feeding period, approximately the same number of animals from each experimental group within a replicate were shipped to the same commercial packing plant (Cargill, High River, AB) and slaughtered on the same day based on BW at last reimplant. Carcass weight, fat thickness, LM area, marbling score, USDA Quality Grade (QG), and measured USDA Yield Grade (YG) were recorded at the packing plant.

Statistical Analysis

All data were analyzed using the GLIMMIX procedure of SAS (SAS® for Windows, Release 9.2, SAS Institute Inc., Cary, NC). Experimental group was included in the model as fixed effect and replicate was included as a random effect with pen as the experimental unit. When feedbunk sample results were analyzed, experimental group was included in the model as fixed effect and week sampled was included as a random effect. Overall *P*-values were derived from the *F*-test for treatment and comparison and *P*-values were differences of the least square means using p-diff.

Linear and quadratic contrasts were evaluated for all nutrient analysis, feedlot performance, carcass characteristic, and animal health data. The α level for all analyses was ≤ 0.05 .

Results and Discussion

Barley Attributes

Barley descriptive data are presented in Table 3. Differences in digestible energy (DE), acid detergent fiber (ADF), ash, DM, fat, net energy (NE), and CP as predicted by NIRS were observed between HIGH and LOW barley. Digestible energy, DM, fat, net energy, and protein were greater (P<0.01) in HIGH barley compared to LOW. Acid detergent fiber, ash, and crude fiber were greater (P<0.01) in LOW compared to HIGH.

Feedlot Performance

Definitions and calculations for production and performance variables are presented in Table 1, and feedlot performance data are presented in Table 4. Average days on feed were equal at 241 d. Initial BW did not differ (P=0.46) among experimental groups. On a live weight basis, final BW, ADG, and G:F were not different (P \geq 0.11) between the three groups. Overall, heifers gained 1.36 ± 0.02 kg., and averaged 0.155 ± 0.001 for G:F. Weight gain was similar among experimental groups (P=0.22). On a carcass-adjusted basis, final BW, weight gain, ADG, and G:F were also similar (P \geq 0.10) between experimental groups. Overall, heifers gained similarly on a carcass-adjusted basis, averaging 1.42 ± 0.02 kg per day. These performance results are consistent with those of Berry et al. (2004), who also observed no difference in ADG and G:F when different energy and starch concentrations in barley were fed. The feedlot production

results in the current study were in contrast to expectations based on the Nutrient Requirements of Beef Cattle (NRC, 1996) that suggest that as the energy density of the diet increases feedlot performance would be expected to improve. However, the greater starch content of the HIGH energy barley may have limited improvements in cattle performance because cattle fed the HIGH barley consumed more starch or less fiber and likely experienced more subacute acidosis challenges (Stock et al. 1990).

Treatment differences (P<0.01) in addition to a small linear and quadratic increase (P<0.01) were observed for DMI as the DE content of the diet decreased (HIGH 8.26 kg; 50:50 8.32 kg; LOW 8.38 kg). Similarly, Barry et al. (2004) found that calves fed low energy diets consumed 3.7% more (P<0.05) DM than calves fed high-energy diets during the overall feeding period. The linear increase in DMI as DE content decreased is in contrast to results reported previously in which DMI increased as dietary energy levels increased (Fluharty and Loerch, 1996; Lofgreen et al., 1975). Fluharty and Loerch (1996) fed calves four dietary energy concentrations (1.15, 1.21, 1.25, and 1.30 Mcal NE/kg of DM) and found that DMI increased linearly with increasing net energy concentration in corn-based diets.

On a carcass adjusted basis, final BW, weight gain, ADG, and G:F were also not different (P \geq 0.10) between experimental groups. Overall, heifers gained similarly on a carcass-adjusted basis, averaging 1.42 ± 0.02 kg per day. On a live weight basis, final BW, weight gain, ADG, and G:F were not different (P \geq 0.11)between the three groups. Overall, heifers gained similarly, averaging 1.36 ± 0.02 kg per day. Feed efficiency was, on average, 0.155 ± 0.001 kg per kg fed. These performance results are consistent with

those of Berry et al. (2004), who also observed no difference in daily gain and feed efficiency when different energy and starch concentrations were fed. In contrast, Lofgreen et al. (1975) reported a linear increase in ADG of stressed calves fed 0.84, 1.01, or 1.10 Mcal NEg/kg of DM as dietary energy levels increased. The feedlot production results in the current study were also in contrast to expectations based on the Nutrient Requirements of Beef Cattle (NRC, 1996) that suggest that as the energy density of the diet increases feedlot performance would be expected to improve. However, the greater starch content of the HIGH energy barley may have limited improvements in animal performance because cattle fed diets high in starch experience more sub-acute acidosis challenges (Stock et al. 1990) and that cattle offfset these challenges by consuming smaller and more frequent meals, which may explain why heifers fed HIGH barley had slightly lower intakes in the present study.

Ovnell-Roy et al. (1998) evaluated the effects of barley cultivar on feedlot performance and carcass characteristics of beef steers and digestibility of fiber, starch and energy by beef steers. The authors reported that barley cultivars differed in DE and NDF content, and cultivars with low DE content resulted in lower steer performance. In their study, steers fed barley cultivars with greater DE had improved feed efficiency compared to steers fed barley cultivars with lower DE.

Carcass Characteristics

Carcass characteristic data are presented in Table 4. Carcass weight, 12^{th} rib fat thickness, LM area, marbling score, and dressing percentage were not different (P \geq 0.39) among the three experimental groups. Carcass weight averaged 359.1 \pm 2.36 kg.

Twelfth rib fat, LM area, marbling score, and dressing percentage averaged 1.39 ± 0.03 cm, 77.2 ± 0.03 cm², 469 ± 5.0 , and 61.68 ± 0.12 % respectively. Similarly, Overnell-Roy et al. (1998), observed no difference in carcass weight, 12^{th} rib fat, or LM area when barley cultivars differing in DE were fed to steers. In contrast, Ovnell and Nelson (1992) reported differences in carcass weight, back fat thickness, and KPH due to different barley varieties in finishing rations. Yield and quality grade data are presented in Table 5. No differences ($P \ge 0.18$) in USDA yield or quality grade were observed. Similarly, Ovnell-Roy et al. (1998) reported no differences in yield or quality grade in steers fed barley cultivars with different DE content.

Animal Health

Animal health data are presented in Table 6. No differences (P≥0.18) in the percentage of animals pulled for initial treatment of respiratory disease were observed among experimental groups. The absence of differences in morbidity outcomes in the current study are in contrast to results reported by others. Lofgreen et al. (1975) conducted experiments to determine the effects of increasing energy levels (0.84, 1.01, 1.10, and 1.19 Mcal NEg/kg of DM) on the health and performance of calves. They reported an increase in the number of treatments per calf as the energy density of the diet increased. Berry et al. (2004) found that feeding higher-energy diets decreases the percentage of calves with *Pasteurella multocida* and *Haemophilus somnus* pathogens in calves that receive one or more antimicrobial treatments.

In the present study, there were no differences ($P \ge 0.12$) in the percentage of animals that died as a result of BRD, HS, or lameness. Higher mortality due to metabolic

causes (P=0.02) was observed in the group fed the 50:50 blend, with a significant quadratic effect (LOW 0.53%; 50:50 1.10%; HIGH 0.90%, P=0.02). Due to these differences in metabolic mortality, overall mortality increased linearly (P=0.04) as the energy content of barley increased. A quadratic relationship was also observed for overall mortality (LOW 1.96%, 50:50 3.10%, HIGH 3.00%, P<0.01). These linear relationships may be attributable to the increase in starch or decreases in fiber when comparing the high to low energy barley, with the increase in starch potentially leading to greater and more rapid ruminal degradation and increased metabolic disease. The major site of barley starch digestion is in the rumen, therefore rapid consumption of high grain diets can increase the risk of acidosis (Fulton et al., 1979; Stock et al., 1990).

Conclusions

Low energy barley based diets when segregated by NIRS technology appear to be better than high energy barley diets for DMI, overall mortality and metabolic mortality, with few differences in carcass composition and the number of treatments for respiratory disease. These results would indicate that the low energy barley may be premium to that of the high energy barley. Differences between high quality barley and low quality barley were subtle, so other characteristics may impact performance and be important to consider in future research involving barley segregation. Further research is needed to better understand the performance and health differences when barley is segregated by NIRS using estimated DE content.

References

Adesogan, A.T., Krueger, N.K., and S.C. Kim. 2005. A novel, wireless, automated system for measuring fermentation gas production kinetics of feeds and its application to feed characterization. Anim. Feed. Sci. Technol. 123-124: 211-223.

Ankom. Acid Detergent Fiber in Feeds Filter Bag Technique. Macedon, NY: Ankom Inc.; 2006

Barton, F.E. II and W.R. Windham. 1988. Determination of acid-detergent fiber and crude protein in forages by near-infrared reflectance spectroscopy: collaborative study. J. Assoc. Off. Anal. Chem. 71:1162-1167.

Beauchemin, K.A., Jones, S.D.M., Rode, L.M., and V.J.H. Sewalt. 1997. Effects of fibrolytic enzymes in corn or barley diets on performance and carcass characteristics of feedlot cattle. Can J. Anim. Sci. 77:646-653.

Bengtsson S. and K. Larson. 1984. Prediction of the nutritive value of forages by near infrared re-flectance photometry. J. Sci. Food Agric. 35:951-958.

Berry, B.A., Krehbiel. C.R., Confer, A.W., Gill, D.R., Smith, R.A., and M. Montelongo. 2004. Effects of dietary energy and starch concentrations for newly received feedlot calves: I. Growth performance and health. J. Anim. Sci. 82:837-844.

Bhatty, R.S., Berdahl, J.D., and G.I. Christison. 1975. Chemical composition and digestible energy of barley. Can. J, Anim. Sci. 55: 759-764.

Bhatty, R.S., Christison, G.I., Sosulski, F.W., Harvey, B.L., Hughes, G.R., and J.D. Berhahl. 1974. Relationships of various physical and chemical characters to digestible energy in wheat and barley cultivars. Can. J, Anim. Sci. 54:419-427.

Boss, D. L., and J. G. P. Bowman. 1996. Barley varieties for finishing steers: I. Feedlot performance, in vivo diet digestion, and carcass characteristics. J. Anim. Sci. 74:1967-1972.

Bowman, J. G. P., T. K. Blake, L. M. M. Surber, D. K. Habernicht, and H. Bockelman. 2001. Feed-quality variation in the barley core collection of the USDA national small grains collection. Crop. Sci. 41:863-870.

Dew, D.A. and V.M. Bendelow. 1963. The effect of swathing at different stages of maturity on the malting quality of barley. Can. J. Plant. Sci. 43: 534-541.

Edney, M.J., Morgan, J.E., Williams, P.C., and L.D. Campbell. 1994. Analysis of feed barley by near infrared reflectance technology. J. Near Infrared Spectrosc. 2:33-41.

Fife, T.E., Szasz, J. I., Hunt, C. W. and J. A. Ahola. 2008. Relationship between quality characteristics of barley grain and digestibility in feedlot steers. PAS. 24: 560-565.

Fulton, W. R., Klopfenstein, T. J., and R. A. Britton. 1979. Adaptation to high concentrate diets by beef cattle. 1. Adaptation to corn and wheat diets. J. Anim. Sci. 49:775–784.

Helrich, K., and Padmore, J.M. 1990. Association of Official Analytical Chemists. Official Methods of Analysis (15th Ed.) Vol. 1. Arlington, VA.

Hinman, D. D. 1979. A comparison of malting vs. feed barley varieties on beef cattle performance. Proc. West. Sect. Am. Soc. Anim. Sci. 30: 49–51.

Kemalyan, R. K., Petersen, M. K., Newman, C. W., Clark, C. K., Roth, N. J., Thomas, V. M. and McGuire, C. 1990. Effect of barley cultivar on digestive responses in mature rambouillet ewes. Proc. West. Sec. Am. Soc. Anim. Sci. 41: 415–417.

Kim, H.O. and Williams, P.C. 1990. Determination of starch and energy in feed grains by near-infrared reflectance spectroscopy. J. Agric. Food Chem. 38:682–688

Littell, R. C., G. A. Milliken, W. W. Stroup, R. D. Wolfinger, O. Schabenberger. 2006. SAS® for Mixed Models, Second Edition. SAS Publishing, Cary, NC.

Lofgreen, G. P., J. R. Dunbar, D. G. Addis, and J. G. Clark. 1975. Energy level in starting rations for calves subjected to marketing and shipping stress. J. Anim. Sci. 41:1256–1265.

Lundburg, K. M., Hoffman, P. C., Bauman, L. M. and P. Berzaghi. 2004. Prediction of forage energy content by near infrared spectroscopy and summative equations. PAS. 20: 262-269.

Miller, M. C. 1992. Nutrient composition of Pacific Northwest barley and effect of starch type and β -glucan and fibre levels on its energy content for poultry and swine. Master's thesis. Washington State University, Pullman, WA.

National Research Council, Nutrient Requirements for Beef Cattle, 7th Revised Edition, National Academy Press, Washington DC.

Norris, K.H., Barnes, R.F., Moore, J.E., and J.S. Shenk. 1976. Predicting forage quality by infrared reflectance spectroscopy. J. Anim. Sci. 43: 889-897.

Ovenell-Roy, K.H., Nelson, M.L., Froseth, J.A., Parish, S.M., and E.L. Martin. 1998. Variation in chemical composition and nutritional quality among barley cultivars for ruminants. 1. Steer finishing performance, diet digestibilities and carcass characteristics. Can. J. Anim. Sci. 78:369-375.

Ovenell, K. H., M. L. Nelson, J. A. Froseth, S. M. Parish, and E. L. Martin. 1993. Feedlot performance, carcass characteristics of steers, and digestibility of diets containing different barley cultivars. Proc. West. Sect. Am. Soc. Anim. Sci. 44:416.

Reynolds, W. K., C. W. Hunt, J. W. Eckert, and M. H. Hall. 1992. Evaluation of the feeding value of barley as affected by variety and location using near infrared reflectance spectroscopy. Proc. West. Sec. Amer. Soc. Anim. Sci. 43:498-501.

Sanford, B.J., Grove, A.V. and C. W. Hunt. 2003. Evaluation of barley characteristics that are associated with digestible energy for beef cattle. PAS. 19: 281-285.

Shenk, J.S., Westerhaus, M.O., and M.R. Hoover. 1976. Analysis of forage by infrared reflectance. J. Dairy. Sci. 62:807-812.

Stock, R.A., Sindt, M.H., Parrot, J.C., and F.K. Goedeken. 1990. Effects of grain type, roughage level and monensin level on finishing cattle performance. J. Anim. Sci. 68:3441-3455.

Taylor, P. 1985. The nutritional value of barley for growing swine and finishing steers. Master's thesis. Washington State University, Pullman, WA.

Williams, P.C., Preston, K.R., Norris, K.H., and P.M. Starkey. 1984. Determination of Amino Acids in Wheat and Barley by Near-Infrared Reflectance Spectroscopy. J. Food. Sci. 49:17-20.

Valdes, E.V., Young, L.G., Leeson, McMillan, I., Portela, F., and Winch, J.E. 1985. Application of Near Infrared Reflectance Spectroscopy to Analyses of Poultry Feeds. Poult Sci. 64:2136-2142.

Table 1. Definitions and calculations for cattle production lot variables from a study evaluating the effects of feeding high and low energy barley on feedlot cattle performance in western Canada

Animal Health Rates		
Initial UF Treatment	=	# of animals initially treated for UF divided by the # of animals
Initial NF Treatment	=	# of animals initially treated for NF divided by the # of animals
Overall Chronicity	=	# of animals with chronic disease divided by the # of animals
Overall Wastage	=	# of animals with chronic disease that didn't die divided by the #
		of animals
Overall Mortality	=	# of mortalities (all causes) divided by the # of animals
BRD Mortality	=	# of mortalities due to BRD divided by the # of animals
HS Mortality	=	# of mortalities due to histophilosis divided by the # of animals
Lameness Mortality	=	# of mortalities due to lameness divided by the # of animals
Metabolic Mortality	=	# of mortalities due to metabolic disease divided by the # of animals
Other Mortality	=	# of mortalities (causes other than BRD, HS, lameness, or
		metabolic disease) divided by the # of animals
Production Variables		
Slaughter Weight	=	the total net live weight by multi-pen lots prior to slaughter divided
		by the # of animals sold and represents the average net live weight
W : 1 · C :		of animals sold for slaughter
Weight Gain	=	average slaughter weight minus the average initial weight and
C W-:-1-4		represents the average weight gain of animals sold for slaughter
Carcass Weight	=	total carcass weight at slaughter divided by the # of animals sold
		and represents the average carcass weight of animals sold for slaughter
Dressing Percentage	=	total carcass weight at slaughter divided by the total weight at
Diessing i ciccinage	_	slaughter expressed as a percentage
Days on feed	=	average slaughter date minus the average allocation date and
Days on recu		represents the average # of days on feed of animals sold for
		slaughter
DMI	=	total quantity of feed consumed (100% dry matter basis) divided
		by the # of cattle days and represents the pounds of feed consumed
		per animal per day
Feedlot Performance V	ariable	
ADG ¹ –LWB ²	=	(total net slaughter weight plus total weight of animals shipped for
		salvage slaughter plus total weight of animals that died minus total
		initial weight) divided by the # of animals days
ADG^1 – CAB^2	=	(total carcass weight divided by a fixed dressing percentage
		(60.0%) plus total weight of animals shipped for salvage slaughter
		plus total weight of animals that died minus total initial weight)
1 2		divided by the # of animal days
$G:F^1 - LWB^2$	=	DMI divided by ADG – LWB
$G:F^1 - CAB^2$	=	DMI divided by ADG – CAB
1 TITE: 1:00 .:	1 C	ME' C DDD' 1 ' ' I' MG' 1 '

UF is undifferentiated fever, NF is no fever, BRD is bovine respiratory disease, HS is lesions consistent *Histophilus somni* infection, BVD is bovine viral diarrhea, DMI is daily dry matter intake, ADG is average daily gain, G:F is gain to dry matter intake ratio.

² LWB is live weight basis and CAB is carcass-adjusted basis.

Table 2. Diet composition and chemical analyses of the total mixed rations fed in a study evaluating the effects of feeding high and low energy barley on feedlot cattle performance in western Canada

	<u>Treatment¹</u>					Contrasts	
Item ²	LOW	50:50	HIGH	SEM	P - value	Linear	Quadratic
Ingredient							
LOW Barley	90.08	45.04	-				
HIGH Barley	-	45.04	90.08				
Silage	5.00	5.00	5.00				
Tallow	2.00	2.00	2.00				
Supplement ³	2.92	2.92	2.92				
Nutrient ⁴							
Number of Samples	6	6	6	6			
Dry Matter	80.0	80.7	80.5	0.34	0.11	0.15	0.02
Crude Protein	10.2	10.1	10.3	0.09	0.26	0.24	0.53
Acid Detergent Fiber	7.6	7.1	8.4	0.52	0.19	0.27	0.20
Calcium	1.24	1.28	1.14	0.16	0.82	0.68	0.72
Phosphorous	0.28	0.28	0.28	0.01	0.94	0.74	0.67

Animals in the LOW group were fed diets containing low energy barley, as determined by NIRS. Animals in the 50:50 group were fed a 50:50 blend of low and high energy barley, as determined by NIRS. Animals in the HIGH group were fed high energy barley, as determined by NIRS.

^{2.} All numbers are expressed as percentages on a 100% DM basis.

^{3.} Supplement was manufactured at Landmark Feeds (Strathmore, AB) and included 27.6 mg/kg DM monensin (Rumensin, Elanco Animal Health, Indianapolis, Indiana), 12.1 mg/kg DM tylosin (Tylan, Elanco Animal Health), and 0.5 mg/heifer daily melengestrol acetate (MGA, Pfizer Animal Health, Kirkland, QC).

^{4.} Analysis was performed by Benchmark Labs, Calgary, AB.

Table 3. Barley descriptive data measured by Near Infrared Spectroscopy (NIRS) in a study evaluating the effects of feeding high and low energy barley on feedlot cattle performance in western Canada

	Trea	tment		
Item	LOW	HIGH	SEM	P - value
Number of samples	241	248	-	-
DM, %	86.92	87.23	0.06	< 0.01
Acid Detergent Fiber, %	6.45	5.81	0.09	< 0.01
Ash, %	2.40	2.28	0.01	< 0.01
Fat, %	1.72	1.90	0.02	< 0.01
Digestible Energy, Mcal/kg DM	1529.4	1557.9	1.80	< 0.01
Net Energy, Mcal/kg DM	1530.22	1557.82	1.09	< 0.01
Protein, %	11.89	12.19	0.11	< 0.01

Results were obtained using NIRS (Near-infrared spectroscopy, InfraXact NIRS, FOSS North America, Eden Prairie, MN) at the time of arrival at the feedlot.

Table 4. Feedlot performance data summary from a study evaluating the effects of feeding high and low energy barley on feedlot cattle performance in western Canada

		Treatment	1			<u>Contrasts</u>			
Item	LOW	50:50	HIGH	SEM	P - value	Linear	Quadratic		
Days on Feed	241	241	241	-	-	-	_		
Carcass Adjusted Performa	nce^2								
Final BW, kg	596.0	598.3	598.6	3.91	0.55	0.32	0.55		
Weight Gain, kg	323.4	320.2	317.5	4.67	0.10	0.03	0.06		
DMI, kg/d	8.38	8.32	8.26	0.07	< 0.01	< 0.01	< 0.01		
ADG, kg	1.43	1.43	1.41	0.02	0.23	0.10	0.35		
G:F	0.163	0.164	0.164	0.06	0.67	0.48	0.51		
Live Performance									
Initial BW, kg	254.8	256.0	258.0	4.59	0.46	0.25	0.23		
Final BW, kg	584.7	584.3	582.3	3.14	0.43	0.20	0.43		
Weight Gain, kg	311.7	310.1	308.4	4.17	0.22	0.09	0.13		
ADG, kg	1.37	1.37	1.35	0.02	0.11	0.04	0.15		
G:F	0.155	0.156	0.155	0.001	0.74	0.62	0.70		
Carcass characteristics									
HCW, kg	359.7	359.4	358.1	2.36	0.57	0.33	0.51		
12 th Rib Fat, cm	1.40	1.38	1.40	0.03	0.39	0.80	0.37		
LM Area, cm ²	77.0	77.2	77.4	0.34	0.74	0.44	0.52		
Marbling Score ³	469	470	468	4.96	0.74	0.73	0.96		
Dressing Percentage ⁴	61.66	61.71	61.66	0.12	0.92	0.99	0.11		

Animals in the LOW group were fed diets containing low energy barley, as determined by NIRS. Animals in the 50:50 group were fed a 50:50 blend of low and high energy barley, as determined by NIRS. Animals in the HIGH group were fed high energy barley, as determined by NIRS. In each experimental group, there were 10 pens. A total of 3,000 animals were allocated to HIGH and 50:50, and 3,007 animals to LOW.

². Carcass adjusted values were calculated using carcass weights converted to live weights using a fixed dressing % of 60.0%.

^{3.} Marbling Score 600=Modest, 500=Small, 400=Slight

^{4.} Dressing % of cattle marketed in Canada will differ from that of similar animals marketed in the United States. The US carcass weight includes the weight of the kidney, pelvic and heart fat.

Table 5. USDA Yield Grade and Quality Grade distribution summary from a study evaluating the effects of feeding high and low energy barley on feedlot cattle performance in western Canada

		Treatment ¹		Co	ntrasts_		
Item	LOW	50:50	HIGH	SEM	P - value	Linear	Quadratic
USDA Yield Grade	?						
YG1	2.86	3.62	3.59	0.66	0.18	0.12	0.07
YG2	21.71	22.67	23.50	2.01	0.19	0.07	0.11
YG3	42.29	41.83	41.70	1.07	0.87	0.61	0.60
YG4	26.95	24.78	25.53	1.94	0.10	0.16	0.05
YG5	6.19	7.10	5.68	1.14	0.58	0.71	0.87
USDA Quality Grad	de						
Prime	0.28	0.10	0.11	0.08	0.08	0.05	0.03
Choice	32.74	34.79	33.37	1.94	0.45	0.34	0.35
Select	40.70	38.61	39.95	0.95	0.31	0.62	0.23
Standard	26.29	26.50	26.58	1.96	0.97	0.22	0.80

Animals in the LOW group were fed diets containing low energy barley, as determined by NIRS. Animals in the 50:50 group were fed a 50:50 blend of low and high energy barley, as determined by NIRS. Animals in the HIGH group were fed high energy barley, as determined by NIRS.

². All numbers are expressed as percentages.

The Yield Grade (YG) and Quality Grade (QG) values represent the proportion of carcasses within each group that received each YG.

Table 6. Morbidity and mortality data summary from a study evaluating the effects of feeding high and low energy barley on feedlot cattle performance in western Canada

		Treatment ¹				Cor	<u>Contrasts</u>	
Item ³	LOW	50:50	HIGH	SEM	P - value	Linear	Quadratic	
<i>Morbidity</i> ³								
Initial UF ² Treatment	3.76	3.57	4.06	0.18	0.64	0.61	0.91	
Initial NF ² Treatment	0.60	0.77	0.93	0.21	0.18	0.09	0.08	
<i>Mortality</i> ³								
Overall Mortality	1.96	3.10	3.00	0.13	0.04	0.04	< 0.01	
BRD Mortality	0.47	0.43	0.57	0.25	0.63	0.68	0.84	
HS Mortality	0.53	0.67	0.43	0.26	0.43	0.44	0.89	
Lameness Mortality	0.03	0.10	0.20	0.62	0.12	0.13	0.14	
Metabolic Mortality	0.53	1.10	0.90	0.20	0.02	0.09	0.02	
Miscellaneous Mortality	0.40	0.80	0.87	0.25	0.07	0.07	0.04	

Animals in the LOW group were fed diets containing low energy barley, as determined by NIRS. Animals in the 50:50 group were fed a 50:50 blend of low and high energy barley, as determined by NIRS. Animals in the HIGH group were fed high energy barley, as determined by NIRS.

All numbers are expressed as percentages.
UF is undifferentiated fever, NF is no fever.

CHAPTER III: NUTRIENT MASS BALANCE AND PERFORMANCE OF FEEDLOT CATTLE FED BARLEY BASED DIETS WITH AND WITHOUT DISTILLERS GRAINS PLUS SOLUBLES

E.M. Hussey*, G.E. Erickson*, R.E. Peterson[‡], and L.O. Burciaga-Robles[‡]

*Department of Animal Science, University of Nebraska, Lincoln 68583,[‡]Feedlot Health

Management Services Ltd., Okotoks, AB, Canada T1S 2A2

Abstract

Crossbred yearling heifers (n=9,538, 32 pens, 492 ± 50 kg initial BW, days on feed=81) were blocked by BW and assigned randomly at reimplant to a 2 x 2 factorial arrangement of treatments. Main effects included LOW or HIGH starch:neutral detergent fiber (NDF) barley and 0 or 20% inclusion of dried distillers grains plus solubles (DDGS). Barley was determined to be HIGH (starch:NDF > 3.25) or LOW (starch:NDF < 3.25) at feedlot arrival based on values determined by Near Infrared Spectroscopy. The objective was to evaluate the impact of HIGH or LOW barley and 0% or 20% DDGS on feedlot performance, carcass characteristics and nutrient mass balance. No barley x DDGS interactions were observed. Intake, ADG, and HCW were greater (P<0.02) and carcass adjusted G:F tended to be greater (P=0.10) for LOW starch:NDF barley compared to HIGH. Barley treatment did not affect yield or quality grade ($P \ge 0.18$). Intake, retention, and excretion of N and P were greater ($P \le 0.01$). Loss and excretion of N on a kg per heifer basis was greater (P=0.05) for LOW, but was not different when expressed as a % of N excretion, averaging 85%. Intake was greater and G:F based on live ADG was lower (P<0.01), and G:F tended to be lower on a carcass basis (P=0.07) for 20% compared to 0% DDGS. Fat depth and the percentage of Yield Grade 4 carcasses were greater (P≤0.05) for 20% DDGS compared to 0%, but no differences in quality grade were observed (P≥0.25). Intake and excretion of N and P were greater (P<0.01) for 20% DDGS. Removal of N, P, and DM were not different (P≥0.17) between 0 and 20% DDGS. Losses of N (82% vs. 87%) and P were greater (P≤0.01) for 20% compared to 0%. Feeding low starch:NDF barley improved feedlot performance, increased DM removed from the pen, and increased N loss. Feeding 20 % DDGS increased DMI, had a slight negative impact on G:F, and increased N and P losses.

Key words: barley, distillers grains plus solubles, mass balance

Introduction

Barley is a major cereal grain used for feeding cattle in Western Canada and the Pacific Northwest. Previous in-house research segregating barley using Near Infrared Spectroscopy (NIR) based on a digestible energy calculation into high and low energy barley and feeding high, low, or a 50:50 blend of the two (Hussey et al., 2012). Overall mortality increased by increasing NIRS predicted barley energy, most of which were metabolic and miscellaneous. However, G:F on an adjusted carcass weight basis was improved for the low energy barley. Results of this trial did not support the original hypothesis that greater DE content of barley would improve performance, indicating that additional research was needed to better understand NIRS as a tool for feed commodity valuation. Based on animal performance, morbidity/mortality, and carcass characteristics from this initial trial, a follow up study was designed using starch:neutral detergent fiber

(NDF) ratio to more accurately identify barley that was considered to be high risk for affecting animal performance and morbidity/mortality.

Expansion of the ethanol industry has led to increased availability of dried distillers grains plus solubles (DDGS). During the dry milling process, starch is removed and fermented to produce ethanol, resulting in a 3-fold increase of all other nutrients (Klopfenstein et al., 2008). Feeding DGS has been shown to improve ADG and G:F (Klopfenstein et al., 2008, Walter et al., 2010) with no deleterious effects on carcass quality. When DGS are fed as an energy source (greater than 20% of diet DM), protein and phosphorus exceed NRC requirements due to the increase in nutrient content (Klopfenstein et al., 2008). Inclusion of distiller's grains therefore increases nutrients excreted in manure, which in turn impacts the fertilizer value of manure (Luebbe et al., 2011; Bremer et al., 2009). The excess nitrogen (N) and phosphorus (P) excreted can create environmental issues, as there is the potential to impact air and water quality. Phosphorus in the manure is not volatilized so most of the P excreted is in the manure and runoff (Klopfenstein and Erickson, 2002). Nitrogen, however, may be volatilized and lost from the pen surface as ammonia with increasing dietary N (Erickson and Klopfenstein, 2010) and increasing DGS (Luebbe et al., 2011).

The objective of this study was to evaluate the impact of HIGH or LOW barley and 0% or 20% DDGS on feedlot performance, carcass characteristics, and N and P mass balance in commercial sized pens.

Materials and Methods

All procedures involving live animals were approved by the Feedlot Health

Management Services Ltd. (FHMS) Animal Care and Use Committee with informed

consent from the animal owners.

Study Facilities

The study was conducted at Western Feedlots Ltd.- High River, a commercial feedlot near High River, AB, Canada. The cattle were housed in standard facilities for western Canada including open-air, dirt-floor pens with central feed alleys and 20% porosity wood-fence windbreaks. Animal handling facilities had a hydraulic chute equipped with an individual animal scale, a chute-side computer with individual animal data collection, management software (*i*FHMS, Feedlot Health Management Services Ltd., AB, Canada) and separation alleys to facilitate the return of animals to designated pens.

Study Animals

At the time of reimplant, each animal was individually weighed (Model LS51208, Cardinal Scale Manufacturing Co. Webb City, MO), and given an infectious bovine rhinotracheitis (IBR) virus, parainfluenza-3 (PI₃) virus, bovine viral diarrhea (BVD) virus (types I and II) and bovine respiratory syncytial virus combination vaccine (Bovi-Shield[®] Gold 5, Pfizer Animal Health, Kirkland, QC, and a Synovex® Choice implant (Pfizer Animal Health, Pfizer Canada Inc., Kirkland, QC).

Experimental Design

Crossbred yearling heifers (n=9,538, 492 ± 50 kg initial BW, days on feed=81) were assigned randomly at the time of reimplant to a 2 x 2 factorial arrangement of

treatments and fed for an additional 84 d from February to July 2010. Main effects included LOW or HIGH starch:NDF barley and 0 or 20% inclusion of DDGS. Study animals were housed by experimental group in commercial feedlot pens and followed from allocation until slaughter.

Barley was determined to be HIGH (starch:NDF > 3.25) or LOW (starch:NDF < 3.25) at feedlot arrival based on values determined by NIRS. The cutoff value of 3.25 resulted in one third of the barley that arrived at the feedlot would be HIGH starch:NDF barley (Figure 1). Mean and SD for starch:NDF for HIGH and LOW was 3.48 ± 0.26 and 2.94 ± 0.25 , respectively. Once a shipment of barley was determined to be HIGH or LOW, it was tempered to 18.5% moisture, rolled, and stored by barley treatment. A surfactant (Grain Prep Processing Aid, Agri Chem, Inc., Ham Lake, MN) was also added to the barley at time of processing.

Complete feedlot diets (presented in Table 2) and water were offered *ad libitum* throughout the feeding period. Dietary starch content was 53.1% for HIGH/0DDGS, 39.5% for HIGH/20DDGS, 50.2% for LOW/0DDGS, and 34.1% for LOW/20DDGS. Dietary NDF content was 15.1% for HIGH/0DDGS, 21.0% for HIGH/20DDGS, 15.9% for LOW/0DDGS, and 20.2% for LOW/20DDGS. The DDGS fed throughout the study was, on average, 31.65% CP, 36.23% NDF, 0.84% P, and 0.63% S. Feedlot diets were blended in truck-mounted mixer boxes (Cattlelac, Reg Cox Feed Mixers Inc., Red Deer, AB Canada) equipped with electronic load cells. Diets were delivered to the pens once daily at 0700 and daily feed allowances to each pen were recorded using the feedlot

administrative software (Feedback, ComputerAid Professional Services Ltd., Okotoks, AB). Ration changes occurred on the same day within each replicate.

The supplement included in the ration was manufactured at a commercial feed mill (Landmark Feeds, Strathmore, AB). Monensin was included in the diet at 27.6 mg/kg DM (Rumensin[®], Elanco Animal Health, Indianapolis, IN), tylosin included at 12.1 mg/kg DM (Tylan[®], Elanco Animal Health), and melengestrol acetate was included at 0.5 mg/heifer daily (MGA[®], Pfizer Animal Health).

Feedbunk samples were collected twice monthly. For each pen, equal sized feed samples were collected from the beginning, middle, and end of the bunk. On each sampling day, samples from each pen in an experimental group were composited to form one sample for each experimental group. Samples were frozen until the end of the study. Samples were submitted to a commercial lab (DairyOne, Ithaca, NY) for DM (Georing and Van Soest, 1970), crude protein (CP, AOAC 990.03), ash (AOAC Method 942.05), fat (AOAC 2003.05), NDF (solutions as in Van Soest, P.J., methods as in ANKOM Technology Method 6), starch, P, and potassium (K). For P and K, samples were predigested at ambient temperature 15 minutes with 8ml nitric acid (HNO₃) and 2ml hydrochloric acid (HCl) then the temperature was increased to 190°C in 15 minutes and held at digestion temperature of 190°C for 15 minutes. Vessels brought to 50-ml volume aliquot used for analysis. Samples were analyzed using an Intrepid Inductively Coupled Plasma (ICP) Radial Spectrometer after microwave digestion (CEM Application Note for Acid Digestion, Matthews, NC) (Wolf et al., 2003). Starch samples were pre-extracted for sugar by incubation in 40°C water bath and filtration on Whatman 41 filter paper.

Residues were thermally solubilized using an autoclave, and then incubated with glucoamylase enzyme to hydrolyze starch to produce dextrose (glucose). Prepared samples were injected into a sample chamber of YSI Analyzer where dextrose diffuses into a membrane containing glucose oxidase. The dextrose was immediately oxidized to hydrogen peroxide and D-glucono-4-lactone. The hydrogen peroxide is detected amperometrically at the platinum electrode surface. The current flow at the electrode is directly proportional to the hydrogen peroxide concentration, and hence to the dextrose concentration. Starch was determined by multiplying dextrose by 0.9 (YSI Incorporated Life Sciences, Yellow Springs, OH).

Animal Health and Marketing

Experienced animal health personnel observed the study animals once daily for evidence of disease. Animals deemed to be "sick" by the animal health personnel, based on subjective criteria such as general appearance, attitude, gauntness, reluctance to move, etc., were individually sorted from pen mates, moved to the hospital facility, diagnosed, and treated as per the standard feedlot protocol. The treatment events including the treatment date, the presumptive diagnosis, drug(s) administered, and dose(s) used were recorded.

The case definition for undifferentiated fever (UF) was a lack of abnormal clinical signs referable to body systems other than the respiratory system, a rectal temperature ≥ 40.6°F, and no previous treatment history. The case definition for no fever (NF) was a lack of abnormal clinical signs referable to body systems other than the respiratory system, a rectal temperature < 40.6°F, and no previous treatment history for UF. Animals

identified as "sick" subsequent to the third relapse therapy for each disease in the treatment protocol were deemed to be "chronics". Also, animals that were unsuitable to be returned to their designated feedlot pens, based on subjective appraisal of the attitude and appearance of each animal, were deemed to be "chronics". Chronics that did not die during the study were defined as wastage. Chronics and wastage were included in the performance calculations, described in Table 1.

A gross necropsy examination was performed on each animal that died during the study period by trained personnel from Feedlot Health Management Services Ltd. (FHMS). All animals that died were weighed by feedlot personnel. Animals that died as a result of bovine respiratory disease (BRD) were classified as BRD mortalities. Animals that died as a result of lesions consistent with *Histophilus somni* (HS) infection were classified as HS mortalities. Animals that died as a result of lameness (arthritis, foot rot, or foot lesions) were classified as lameness mortalities, and animals that died as a result of metabolic disease (atypical interstitial pneumonia, bloat, chronic rumenitis, enterotoxemia, laminitis, liver abscesses, overload, or posterior vena cava thrombosis) were classified as metabolic mortalities. Animals that died of miscellaneous causes (causes other than causes other than BRD, HS, lameness, or metabolic disease) were classified as miscellaneous mortalities. Overall mortality is the sum of all mortalities throughout the study period. Weights of animals that died or were shipped for salvage slaughter during the study were included in the performance calculations.

At the end of the feeding period, heifers were shipped for slaughter according to BW strata identified at reimplant. Ultra-heavy and heavy heifers at the time of reimplant were shipped for slaughter first, followed by middle weight heifers, and then light weight

heifers. All cattle were slaughtered at the same commercial packing plant (Cargill, High River, AB) and approximately the same number of animals per treatment within a replicate were shipped for harvest on a given day. Carcass weight, fat thickness, LM area, marbling score, USDA Quality Grade (QG), and measured USDA Yield Grade (YG) were recorded at the packing plant.

Nutrient Balance

Nutrient mass balance was conducted using 32 open-air feedlot pens. Since the feedlot was a large commercial yard, runoff from the 32 trial pens was not separated from runoff from the rest of the feedlot. Previous research indicates that runoff represents less than 5% of the total nutrient loss (Quinn et al., 2007; Luebbe et al., 2009; Rich et al., 2011) and was therefore assumed in the nutrient losses. Pens were cleaned initially at the time of reimplant while pens of cattle were at the rehandling facility. Once all of the heifers in a pen had been shipped for harvest, pens were cleaned by scraping manure into a pile in the middle of the pen and loaded into a tractor-trailer using a loader tractor. Trucks hauling manure were weighed using an 80 ton scale (model 777, Cardinal Scale Manufacturing Co. Webb City, MO). Two composite manure samples were taken as the pile was hauled out of the pen by collecting 20 sub-samples per composite. Composites were submitted to Agri-Food Laboratories, (Guelph, ON, Canada) for nutrient analysis. All samples were analyzed for DM (Helrich, K., and Padmore, J.M. 1990), organic matter (OM AOAC method 967.05), N (AOAC method 990.03); P, Ca and K (AOAC method 985.01), pH, and starch (AOAC method 996.11).

Feedbunks and feed ingredients were sampled every 2 weeks to determine nutrient intake by pen. Retained heifer N and P were calculated using the energy, protein, and P equations (NRC, 1996). Nutrient excretion was determined by subtracting nutrient retention from intake (ASABE, 2005). Total N lost (kg/heifer) was calculated by subtracting manure N from excreted N. Percentage of N lost was calculated as N lost divided by N excretion. Total P lost (kg/heifer) was calculated by subtracting manure P from excreted P. Percentage of P lost was calculated as P lost divided by P excretion.

Statistical Analysis

All data were analyzed using the mixed procedure of SAS (SAS® for Windows, Release 9.2, SAS Institute Inc., Cary, NC). Treatment was included in the model as fixed effects and replicate was included as a random effect. Pen served as the experimental unit. When feedbunk sample results were analyzed, experimental group was included in the model as fixed effect and week sampled was included as a random effect. For each outcome analyzed, interactions between barley and DDGS treatment were tested. If no barley x DDGS interaction was observed, the interaction term was removed from the model and the outcome was re-analyzed and presented as main effect of barley type or DDGS concentration. Overall P-values were derived from the F-test for treatment and comparison and P-values were differences of the least square means using p-diff. The α level for all analyses was ≤ 0.05 , with P-values from 0.05 to ≤ 0.10 considered tendencies.

Results and Discussion

Feedlot Performance and Carcass Characteristics

Feedlot performance data are presented in Table 4. No barley x DDGS interactions (P≥0.19) were observed when feedlot performance data were analyzed, therefore only main effects are presented. Initial BW was not different (P=0.79) between the two barley treatments. Intake was 0.3 kg/d greater (P<0.01) for heifers fed LOW starch:NDF barley than heifers fed HIGH. Carcass adjusted ADG was also greater (P=0.02) for heifers fed LOW than HIGH, but carcass adjusted G:F was not different (P=0.25). On a live weight basis, ADG and G:F were not different (P≥0.24) among barley treatments likely due differences in gut fill or dress. Carcass adjusted final BW was 5.6 kg greater (P=0.03) for heifers fed LOW starch:NDF barley compared to heifers fed HIGH. Carcasses from heifers fed LOW were 3.4 kg heavier (P=0.03) than carcasses from heifers fed HIGH. Yield and quality grade data are presented in Table 3. Barley treatment did not affect 12th rib fat, LM area, and marbling score, dressing percentage, USDA QG (P≥0.18).

Starch is the primary nutrient of ruminant diets used to promote high levels of production (Theurer, 1986). However, the major site of barley starch digestion is in the rumen, therefore rapid consumption of high grain diets can increase the risk of acidosis (Fulton et al., 1979; Stock et al., 1990) and have negative effects on cattle performance. In the present study, intake was greater for heifers fed LOW barley compared to HIGH. The primary symptom of subacute acidosis is reduced and erratic feed intake (Cooper et al., 1999). The NRC suggests that one of the factors affecting intake is energy requirement (NRC, 1996). Secondly, Stock et al. (1990) suggested that cattle fed diets high in starch experience more subacute acidosis challenges and offset these challenges

by consuming smaller and more frequent meals. The LOW starch:NDF barley contained less starch and more NDF relative to HIGH starch:NDF, and therefore contained less energy, meaning that the heifers fed LOW would have had to consume more pounds of feed to meet energy requirements compared to HIGH. The observed increase in DMI leading to an increase in ADG suggests acidosis and not energy dilution.

Initial BW was not different (P=0.86) between the two DDGS treatments. Dry matter intake was greater (P<0.01) for 20% compared to 0% DDGS. Carcass adjusted final BW, ADG, and G:F were not affected (P≥0.12) by DDGS treatment. On a live weight basis, ADG and G:F were greater (P≤0.01) for 0% compared to 20% DDGS. Fat depth and the percentage of USDA YG3 and YG 4 carcasses were greater (P≤0.04) for 20% DDGS compared to 0%, but no differences in USDA QG were observed (P≥0.26). A tendency (P≥0.06) towards increased percentage of USDA YG1 and YG2 carcasses was also observed for heifers fed 20DDGS. Carcass weight, LM area, marbling score, and dressing percentage were not affected (P≥0.21) by DDGS treatment.

In the present study, intake was greater for heifers fed 20DDGS compared to 0DDGS. This is in contrast to the findings of Buckner et al. (2008a) who observed no difference (P>0.15) in DMI when 0, 10, 20, 30, or 40% DDGS was fed in corn-based diets. Walter et al. (2010) observed a quadratic response to increasing corn-based DDGS level in barley-based diets, with the highest DMI at 20% DDGS. Mateo et al. (2004) observed the lowest DMI for cattle fed 0% DDGS compared with cattle fed 20 and 40% DDGS in corn-based diets. Because DDGS contains significant amounts of fiber and essentially no starch, adding DDGS to barley-based diets may have the additional benefit

of moderating and stabilizing rumen pH, thus reducing the potential for acidosis (Anderson et al., 2011). Therefore, it is possible that DMI may increase when DDGS are included because of the decrease in dietary starch and reduced risk of subacute acidosis.

The increase in ADG and G:F with 0DDGS compared to 20DDGS is unlike previous observations when DDGS are fed up to 40% of diet DM. The lack of improvement in ADG indicates a possible energy dilution. Buckner et al. (2008a) observed a quadratic response to increasing DDGS level when a dry-rolled corn based diet was fed, with the greatest ADG observed when DDGS was included at 20% of diet DM. Buckner et al. (2008a) also observed that G:F tended (P=0.10) to be quadratic, with 20% inclusion having the greatest value and all other levels were numerically greater than the negative control. Walter et al. (2010) observed no difference (P=0.13) in ADG when corn-based DDGS or wheat-based DDGS were fed at 20% or 40% compared to a negative control in barley-based diets (0% DDGS). The authors also reported a quadratic increase (P<0.01) in G:F in cattle fed corn-based DDGS. Klopfenstein et al. (2008) in a meta-analysis of several studies utilizing corn DDGS up to 40% of the diet reported a cubic trend on G:F with optimal efficiency between 10 and 20% of diet DM, while the 40% inclusion level had a G:F similar to the corn-based control diets. Unlike the findings of the current study, Eun et al. (2009) reported no differences in G:F of cattle fed corn DDGS as a replacement for barley grain at levels up to 18.3% of diet DM, although cornbased DDGS inclusion resulted in a numeric improvement in G:F. The discrepancy between trials on ADG and G:F is unclear, but could be due to grain source, fat, S, or NDF content. In addition, the present study only included the last half (average of 81d) of the feeding period.

Vander Pol et al. (2009) suggested that some of the differences in ADG and G:F among experiments when wet distillers grains plus solubles (WDGS) are fed compared to a negative control may be due to fat content of the distillers grains used, as this will vary with source. In studies documenting nutrient content of WDGS by sampling byproduct from various plants, Buckner et al. (2008b) found that fat content can vary 2 to 5 percentage units depending on the amount of solubles added back to the wet grains.

Sulfur content of DDGS fed was 0.63%, NDF was 36.23%, P was 0.84%, and CP was 31.65%.

In the present study, feeding 20DDGS did not increase carcass weight compared to 0DDGS. These results are consistent with those of Walter et al. (2010) who observed no difference (P=0.54) in HCW when 20% corn-based DDGS was fed compared to a negative control. In contrast to the findings of the present study, Anderson et al. (2011) who evaluated 0, 12, 24, or 36% DDGS in barley-based diets and observed a linear increase (P=0.01) in HCW when any level of DDGS was fed compared to 0% DDGS inclusion. Buckner et al. (2008a) observed a quadratic relationship for HCW (P=0.04), but no other carcass characteristics were affected by DDGS level. In the present study, heifers fed 20DDGS had a greater 12th rib fat thickness and a greater percentage of USDA YG3 and YG4 carcasses. This increase in 12th rib fat thickness was inconsistent with the findings of Walter et al. (2010) who observed no difference (P=0.18) in grade fat at time of slaughter. Anderson et al. (2011) observed a linear increase (P=0.01) in USDA YG and back fat thickness as well as an increase in USDA YG and back fat thickness when any level of DDGS was fed compared to 0% DDGS inclusion.

Animal Health

Morbidity and mortality data are presented in Table 5. No barley x DDGS interactions ($P \ge 0.12$) were observed when feedlot animal health data were analyzed, therefore only main effects are presented. Barley treatment had no effect ($P \ge 0.13$) on first UF, first atypical interstitial pneumonia (AIP), or first lameness treatment. The number of treatments for NF was greater (P=0.02) for heifers fed LOW starch:NDF barley compared to HIGH. The number of bloat treatments was greater (P=0.03) for heifers fed HIGH starch:NDF barley compared to LOW, which may be attributable to the increase in starch or decreases in fiber when comparing the high to low energy barley, with the increase in starch potentially leading to greater and more rapid ruminal degradation and increased metabolic disease. The major site of barley starch digestion is in the rumen, therefore rapid consumption of high grain diets can increase the risk of acidosis (Fulton et al., 1979; Stock et al., 1990). No differences (P=0.52) in overall mortality were observed between barley treatments. However, mortality due to lameness was greater (P=0.04) in heifers fed LOW starch:NDF barley compared to HIGH. Dried distillers grains treatment had no effect ($P \ge 0.13$) on morbidity and mortality outcomes, similar to the results of other studies (Holtshausen et al., 2011; Neville et al., 2010).

Nutrient Balance

Manure nutrient composition data are presented in Table 6. No barley x DDGS interactions (P≥0.14) were observed when manure composition data were analyzed. Dry matter, OM, N, and P content of manure were not affected (P≥0.15) by barley starch:NDF ratio. Phosphorus content of manure was greater (P=0.02) for pens of cattle fed 20DDGS compared to 0DDGS (0.46 vs 0.42%, respectively). Manure N:P ratio was

1.98 for HIGH starch:NDF barley, 2.02 for LOW starch:NDF barley, 2.05 for 0 DDGS, and 1.96 for 20 DDGS. Manure C:N ratio was 0.07 for all treatments.

Kissinger et al. (2007) used data from 6 commercial feedlots (representing 6,366 head of cattle) and observed significant variation among feedlots. The authors hypothesized that the variation is driven by ration nutrient concentration (P only), pen conditions prior to and during manure harvest (N and P), and management choices relative to use of manure in lot maintenance (N and P). The difference in DDGS content of the ration in the present study (0 or 20% DDGS) would drive the difference in manure P concentration. In addition, pens were managed similarly and were in the same environment. Kissinger et al. (2007) also suggested that 33% of excreted N (65 g/animal daily) and 91% of excreted P (32 g/animal daily) are harvested as manure on average. In the present study, on average, manure was 23.67% OM, 0.88% N, and 0.44% P. This is slightly different than the results of Kissinger et al. (2007) who reported manure composition of 30.1% OM in summer and winter, 1.35% N in summer and 1.28% N in winter, and 0.64% P in both summer and winter.

Nitrogen balance data are presented in Table 7. Barley by DDGS interactions were observed for several variables when nutrient balance data were analyzed, therefore the simple effects are presented. Barley by DDGS interactions ($P \le 0.02$) were observed for N excretion, and N loss on a kg/heifer basis. Nitrogen intake, N excretion, N removed, N loss on a kg/heifer basis, N loss expressed as a %, and total manure DM removed from the pen were not different ($P \ge 0.17$) between HIGH and LOW barley treatments. Nitrogen retention was greater (P = 0.03) for the LOW starch:NDF barley

compared the HIGH starch: NDF barley. Differences in N retention could be due to composition of gain, as cattle with a lower BW deposit more lean muscle tissue compared to adipose tissue (Klopfenstein and Erickson, 2002).

A barley x DDGS interaction (P=0.04) was observed for N intake. Nitrogen intakes were lowest (P<0.01) for HIGH/0DDGS at 17.1 kg/heifer, followed by 19.1 kg/heifer for LOW/0DDGS, 26.2 kg/heifer for LOW/20DDGS, and greatest at 27.4 kg/heifer for HIGH/20DDGS (Table 4). The increase in N intake in the DDGS fed heifers is a result of the increased DMI when 20DDGS was fed, but mostly due to the dietary N content. A barley x DDGS interaction was also observed for N excreted (kg/heifer), which was lowest (P<0.01) for HIGH/0DDGS at 15.1 kg/heifer, followed by 16.9 kg/heifer for LOW/0DDGS, 24.0 kg/heifer for LOW/20DDGS, and greatest at 25.4 kg/heifer for HIGH/20DDGS. Total N removed in manure (kg/heifer) was not different $(P \ge 0.17)$ among the four treatments. Similarly, total manure DM removed from the pen was not different (P≥0.18). The current study was conducted at a commercial feedlot and thus runoff from trial pens could not be separated from runoff from non-trial pens. Thus, N in runoff was assumed in nutrient losses. Previous research indicates that runoff represents less than 5% of the total nutrient loss (Quinn et al., 2007; Luebbe et al., 2009; and Rich et al., 2011). A barley x DDGS interaction (P=0.02) was observed when N loss on a kg/heifer basis was analyzed, but was not observed when N loss was expressed as a percentage of N excreted. Amount of N lost to volatilization and runoff (N not accounted for in manure of calculated as retained) on a kg/heifer basis was lowest (P<0.01) for HIGH/0DDGS at 12.7 kg/heifer, followed by 14.2 kg/heifer for LOW/0DDGS, 21.0 kg/heifer for LOW/20DDGS, and greatest at 22.8 kg/heifer for HIGH/20DDGS. Amount

of N lost to volatilization and runoff expressed as a percentage of N excreted was greater (P<0.01) on average for heifers fed 20DDGS compared to 0DDGS (88.6% and 83.1%, respectively). These losses are greater than those reported by Erickson et al. (2010), who observed an average loss of 40.6% in a study comparing conventional to phase-fed cornbased diets (41.1 vs 40.1%, respectively). In a study with the same treatments, Quinn et al. (2006a) fed yearling steers for 117 d in the summer and observed N losses of 70.4% and 66.5% in conventional and phase-fed corn-based diets, respectively. Quinn et al. (2006b) fed calf-fed steers for 176 d in the winter/spring and observed N losses of 53.7% and 48.8% in conventional and phase-fed corn-based diets, respectively.

Volatilization losses were calculated by difference between the amount of nutrients excreted minus the amount removed from the pens. Nitrogen losses in the present study were greater than what has been previously reported (Luebbe at al., 2009; Rich et al., 2011; Sayer et al., 2005), perhaps due to the absence of roughage in the diet and time of pen cleaning. Less than 15% of dietary N is retained by feedlot cattle (Bierman et al., 1996). The remaining 85% is excreted and a portion can be lost by volatilization.

Bierman et al. (1999) conducted a trial to determine the effect of level and source of dietary fiber on N and OM excretion by cattle on finishing diets. One hundred twenty steers were stratified by weight and allotted to one of the following treatments: 7.5% roughage (7.5% R), wet corn gluten feed (WCGF; 41.5% of dietary DM), and all-concentrate corn-based (All Con) diet. Cattle were fed for 87 d during the summer. Nitrogen and OM intake of steers fed WCGF were greater (*P*<0.05) than those of steers fed the other treatments. The WCGF treatment had a greater percentage of fecal N output

(P < .05). The All Con treatment had a greater (P < 0.01) percentage of urinary N than WCGF and 7.5% R diets. The All Con treatment had more (P < 0.01) N and OM in runoff than the other treatments. Eliminating roughage in this experiment changed the site of fermentation, which affected the composition of excreted material. Total amount of N excreted may be more important than route of excretion in decreasing N losses to the environment and maximizing recovery in manure, which may have been the case in the present study.

By increasing the amount of carbon in the manure, it is possible to trap more N in manure and decrease N loss (Erickson and Klopfenstein, 2010). The addition of corn bran can to the diet reduces diet digestibility and therefore, more C is excreted (Erickson and Klopfenstein, 2001). This method is more effective for cattle fed in the winter months than the summer months due to the fact that N volatilization losses are rapid during the warm summer months (Erickson and Klopfenstein, 2010). Adding corn bran at 30% diet DM, N losses were reduced by 20.4% in winter (Erickson et al., 2002). A second possibility for the greater losses is pen conditions in the current study. Pens were cleaned in June and July, following a wet spring. A wet feedlot pen causes the surface to be anaerobic, reducing the amount of nitrification and subsequently increasing volatilization of N as ammonia (Hutchinson et al., 1982).

Phosphorus balance data are presented in Table 8. Barley x DDGS interactions ($P \le 0.05$) were observed for P intake and P excreted. P intake, P excreted, P removed from the pen, P loss on a kg/heifer basis, and P loss expressed as a % were not affected ($P \ge 0.18$) by barley treatment. P retained was slightly greater (P = 0.03) for LOW

starch:NDF barley compared to HIGH starch:NDF barley due to small differences in ADG.

Phosphorus intake was lowest (P<0.01) in HIGH/0 at 2.9 kg/heifer, followed by 3.3 kg/heifer in LOW/0, 4.3 kg/heifer in LOW/20, and greatest in HIGH/20 at 4.4 kg/heifer. A barley x DDGS interaction (P=0.05) was also observed for P excreted. Excretion, which was lowest (P<0.01) for HIGH/0 at 2.2 kg/heifer, followed by LOW/0 at 2.5 kg/heifer, 3.4 kg/heifer in HIGH/20, and greatest for LOW/20 at 3.5 kg/heifer. The amount of P removed in the manure was not different (P≥0.15) among treatments. Similarly, the calculated amount of P retained (kg/heifer over the feeding period) was not affected (P=0.28) by DDGS level. Amount of P lost (P not accounted for in manure) on a kg/heifer basis and when expressed as a percentage of P excreted was greater (P<0.01) for heifers fed 20DDGS compared to 0DDGS (57.6% and 45.5%, respectively).

In dry conditions, P may not be removed during pen cleaning because the soil is not as thoroughly mixed with the manure compared to wet conditions (Luebbe et al., 2012). Thus, the amount of P that is unaccounted for in mass balance studies is often greater during the summer (47.0%) compared to winter (5.8%) (Erickson and Klopfenstein, 2002). However, other authors have reported that a greater amount of P was unaccounted for in the winter (13.1%) compared to the summer (9.8%) (Kissinger et al., 2006a). Phosphorus is much less subject to biological transformation than N (Vasconcelos et al., 2007) and thus is not lost to volatilization but is susceptible to runoff. Water solubility of P in feces and manure is an indicator of the potential for P runoff. The percentage of feedlot feces and manure P that is water soluble is 41% and 24%,

respectively (Bremer et al., 2008). However, the interaction of feces and urine with soil minerals reduces the water solubility of P in manure (feces, urine, and soil mix) relative to feces (Bremer et al., 2008).

Conclusions

Feeding LOW starch:NDF barley increased DMI, final BW on a carcass weight basis and HCW, improved ADG and weight gain on a carcass weight basis, and had no effect on USDA YG or USDA QG. Feeding LOW starch:NDF barley slightly increased N and P retention but did not affect N and P losses. Feeding 20 % DDGS increased DMI, 12th rib fat thickness, the percentage of USDGA YG 3 and YG 4 carcasses. However, feeding 20% DDGS had a slight negative impact on G:F, and increased N and P losses to the environment.

References

- Adams, J.R., Farran, T.B., Erickson, G.E., Klopfenstein, T.K., Macken, C.N., and C.B. Wilson. 2004. Effect of organic matter addition to the pen surface and pen cleaning frequency on nitrogen mass balance in open feedlots. J. Anim. Sci. 82:2153-2163.
- Anderson, V.L., Ilse, B.R., and R. Wiederholt. 2011. Effects of increasing levels of distillers grains in barley-based diets on growing and finishing feedlot performance, carcass traits, and nutrients in manure. Prof. Anim. Sci. 27: 547-552.
- AOAC. 2005. Official Methods of Analysis.18th Edition, Revision 4. AOAC International, Gaithersburg, MD.
- ASAE, 2005. Manure production and characteristics. American Society of Agricultural and Biological Engineers. St Joseph, MI.
- Bierman, S., Erickson, G.E., Klopfenstein, T.K., Stock, R.A., Shain, D.H. 1999. Evaluation of nitrogen and organic matter balance in the feedlot as affected by level and source of dietary fiber. J. Anim. Sci. 77:1645-1653.
- Bierman, S., T. Klopfenstein, R. Stock, and D. Shain. 1996. Evaluation of nitrogen, phosphorus, and organic matter balance in the feedlot as affected by nutrition. Nebraska Beef Cattle Rep. MP 67-A. 74-77.
- Buckner, C.D., Mader, T.L., Erickson, G.E., Colgan, S.L., Mark, D.R., Bremer, V.R., Karges, K.K., and M.L. Gibson. 2008a. Evaluation of dry distillers grains plus solubles on performance and economics of finishing beef steers. Prof.Anim. Sci. 24: 404-410.
- Buckner, C.D., Vanness, S.J., Erickson, G.E., Klopfenstein, T.J., and J.R. Benton. 2008b. Nutrient composition and variation among wet and modified distillers grains plus solubles. J. Anim. Sci. (Suppl. 3) 86:84. (Abstr.)
- Buckner, C.D., Mader, T.L., Erickson, G.E., Colgan, S.L., Karges, K.K., Gibson., M. L. 2007. Optimum levels of dry distillers grains with solubles for finishing beef steers. Nebraska Beef Cattle Report. MP90: 36–38.
- Bremer, V.R., Buckner, C.D., Erickson, G.E., and T.J. Klopfenstein. 2008. Total and water soluble phosphorus content of feedlot cattle feces and manure. Nebraska Beef Cattle Report. MP 91: 69-70.
- Cooper, R.J., Klopfenstein, T.J., Stock, R.A., Milton, C.T., Herold, D.W., and J.C. Parrott. 1999. Effects of imposed feed intake variation on acidosis and performance of finishing steers. J. Anim. Sci. 77:1093-1099.
- Depenbusch, B. E., Coleman, C. M., Higgins, J. J., and J. S. Drouillard. 2009. Effects of increasing levels of dried corn distillers grains with solubles on growth performance, carcass characteristics, and meat quality of yearling heifers. J. Anim. Sci. 87: 2653-2663.

- Erickson, G.E. and T.J. Klopfenstein. 2010. Nutritional and management methods to reduce nitrogen losses from beef feedlots. J. Anim. Sci. 88:E172-E180.
- Erickson, G., and T. Klopfenstein. 2002. Distillers grains for beef cattle. Proc. North Central Distillers Grains Conf., Prior Lake, MN.
- Erickson, G.E., Klopfenstein, T.J., and T. Milton. 2002. Corn bran level in finishing diets and N losses from open-dirt pens. Nebraska Beef Report, MP 79A: 54-57
- Erickson, G.E., Klopfenstein, T.J., Milton, T., and D. Walters. 2000. Dietary phosphorus effects on waste management and nutrient balance in the feedlot. Nebraska Beef Cattle Report. MP 73A:65-67.
- Eun, J.S., ZoBell, D. R., and Wiedmeier, R. D. 2009. Influence of replacing barley grain with corn-based dried distillers grains with solubles on production and carcass characteristics of growing and finishing beef steers. Anim. Feed Sci. Technol. 152: 72-80.
- Gibb, D. J., X. Hao, and T. A. McAllister. 2008. Effect of dried distillers' grain from wheat on diet digestibility and performance in feedlot cattle. Can. J. Anim. Sci. 88: 659-665.
- Goering, H.K. and P.J. Van Soest. 1970. Forage Fiber Analyses (apparatus, reagents, procedures, and some applications). ARS/USDA Handbook No. 379, Superintendent of Documents, US Government Printing Office, Washington, D.C. 20402. p15.
- Fulton, W. R., Klopfenstein, T. J., and R. A. Britton. 1979. Adaptation to high concentrate diets by beef cattle. 1. Adaptation to corn and wheat diets. J. Anim. Sci. 49:775–784.
- Ham, G. A., R. A. Stock, T. J. Klopfenstein, E. M. Larson, D. H. Shain, and R. P. Huffman. 1994. Wet corn distillers byproducts compared with dried corn distillers with solubles as a source of protein and energy for ruminants. J. Anim. Sci. 72: 3246-3257.
- Harrold, R.L. and M.E. Kapphahn. 1997. Nutritional Analysis, Regional Barley Crop Quality Report. North Dakota Barley Council, Minnesota Barley Research and Promotion Council and North Dakota State University.
- Helrich, K., and Padmore, J.M. 1990. Association of Official Analytical Chemists. Official Methods of Analysis (15th Ed.) Vol. 1. Arlington, VA.
- Holtshausen, L., Beauchemin, K.A., Schwartzkopf-Genswein, K.S., González, L.A., McAllister, T.A., and D.J. Gibb. 2011. Performance, feeding behavior and rumen pH profile of beef cattle fed corn silage in combination with barley grain, corn or wheat distillers' grain or wheat middlings. Can. J. Anim. Sci. 91:703-710.
- Hussey, E.M., Erickson, G.E., Peterson, R.E., Burciaga-Robles, L.O., and M.L. May. 2012. Evaluation of the effects of feeding high and low energy barley on feedlot cattle performance in western Canada. In-progress.

- Hutchinson, G. L., Mosier, A. R., and C. E. Andre. 1982. Ammonia and amine volatilization from a large cattle feedlot. J. Environ. Qual. 11:288-293.
- Kissinger, W.F., Koelsch, R.K., Erickson, G.E., and T.J. Klopfenstein. 2007. Characteristics of manure harvested from beef cattle feedlots. Appl. Eng. Agric. 23: 357-365
- Kissinger, W.F., Erickson, G.E., Klopfenstein, T.J., and R.K. Koelsch. 2006. Managing phosphorus in beef feedlot operations. Nebraska Beef Cattle Report. MP 88-A. 94-97.
- Klopfenstein, T. J., G. E. Erickson, and V. R. Bremer. 2008. Board-invited Review: Use of distiller by-products in the beef cattle feeding industry. J. Anim. Sci. 86: 1223-1231
- Luebbe, M.K., Patterson, J.M., Jenkins, K.H., Butttrey, E.K., Davis, T.C., Clarck, B.E., McCollum III, F.T., Cole, N.A., and J.C. MacDonald. 2011. Wet distillers grains plus solubles concentration in steam-flaked corn-based diets: Effects on feedlot cattle performance, carcass characteristics, nutrient digestibility, and ruminal fermentation characteristics. J. Anim. Sci. 4567
- Luebbe, M.K., Erickson, G.E., Klopfenstein, T.K., and M.A. Greenquist. 2012. Nutrient mass balance and performance of feedlot cattle fed corn wet distillers grains plus solubles. J. Anim. Sci. 90:296-306.
- Luebbe, M.K., Erickson, G.E., Klopfenstein, T.K., Greenquist, M.A., and J.R. Benton. 2009. Effect of dietary cation-anion difference on feedlot performance, nitrogen mass balance and manure pH in open feedlot pens. Nebraska Beef Cattle Report. MP92. 91-93.
- Mateo, K.S., Tjardes, K.E., Wright, C.L., Koger, T.J., and B.D. Rops. 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 Rep. 2004–03: 14-19.
- Miller, K. A, M. K. Shelor, G. L. Parsons, and J. S. Drouillard. 2009. Optimal roughage level in finishing diets containing combinations of flaked corn and dried distiller's grains with solubles. J. Anim. Sci. 87(E-Suppl.):191 (Abstr.).
- Neville, B.W., Lardy, G.P., Karges, K.K., Eckerman, S.R., Berg, P.T., and C.S. Schauer. 2010. Interaction of corn processing and distillers dried grains with solubles on health and performance of steers J. Anim. Sci. 90:560-567.
- NRC. 1996. Nutrient Requirements of Beef Cattle. Update 2000. Natl. Acad. Press, Washington, DC.
- Quinn, S.A., Erickson, G.E., Klopfenstein, T.J., Stowell, R.R., and D.M. Sherwood. 2007. Effect of phase feeding protein on cattle performance and nitrogen mass balance in open feedlots. Nebraska Beef Cattle Report. MP90. 52-54.

- Quinn, S., Erickson, G., Klopfenstein, T., Stowell, R. and K. Vander Pol. 2006a. Effect of phase feeding protein on cattle performance and nitrogen mass balance in the summer. J. Anim. Sci.84 (Suppl. 1):121. (Abstr.)
- Quinn, S., Erickson, G., Klopfenstein, T., Stowell, R., Vander Pol, K., and D. Sherwood. 2006b. Effect of phase feeding protein on cattle performance and nitrogen mass balance. J. Anim. Sci. 84(Suppl. 2):132. (Abstr.)
- Rich, A.R., Erickson, G.E., Klopfenstein, T.J., Luebbe, M.K., Benton, J.R., and W.A. Griffin. 2011. Effect of pen cleaning frequency and feeding distillers grains and wheat straw on nutrient mass balance and performance of feedlot steers. Nebraska Beef Cattle Report. MP94. 84-86.
- Sayer, K.M., Erickson, G.E., Klopfenstein, T.J., Vander Pol, K.J., and C.N. Macken. 2005. Effects of corn bran and corn steep inclusion in finishing diets on cattle performance and nitrogen mass balance. Nebraska Beef Cattle Report. MP 83-A. 54-56.
- Speihs, M. J., M. H. Whitney, and G.C. Shurson. 2002. Nutrient database for distiller's dried grains with solubles produced from new ethanol plants in Minnesota and South Dakota. J. Anim. Sci. 80: 2639-2645.
- Stock, R.A., Sindt, M.H., Parrot, J.C., and F.K. Goedeken. 1990. Effects of grain type, roughage level and monensin level on finishing cattle performance. J. Anim. Sci. 68:3441-3455.
- Theurer, C.R. 1986. Grain processing effects on starch utilization by ruminants. J. Anim. Sci. 63:1649-1662.
- Vander Pol, K.J., Luebbe, M.K., Crawford, G.I., Erickson, G.E., and T.J. Kopfenstein. 2009. Performance and digestibility characteristics of finishing diets containing distillers grains, composites of corn processing coproducts, or supplemental corn oil. J. Anim. Sci. 87:639-652.
- Vasconcelos, J.T., Tedesci, L.O., Fox, D.G., Galyean, M.L., and L.W. Greene. 2007. Review: feeding nitrogen and phosphorus in beef cattle production to mitigate environmental impacts. Prof. Anim. Sci. 23:8-17.
- Walter, L. J., J. L. Aalhus, W. M. Robertson, T. A. McAllister, D. J. Gibb, M. E. R. Dugan, N. Aldai and J. J. McKinnon. 2010. Evaluation of wheat or corn distillers' grains with solubles on performance and carcass characteristics of feedlot steers. Can. J. Anim. Sci. 90: 259-269.
- Wolf, A., Watson, M., and N. Wol- 2003. Digestion and dissolution methods for P, K, Ca, Mg and trace elements. Recommended methods of manure analysis. ed J. Peters, pp30, 32-35. University of Wisconsin Extension Publication. A3769.

Table 1. Definitions and calculations for cattle production lot variables from a study evaluating the effects of feeding high and low energy barley on feedlot cattle performance in western Canada

Animal Health Rates		
Initial UF Treatment	=	# of animals initially treated for UF divided by the # of animals
Initial NF Treatment	=	# of animals initially treated for NF divided by the # of animals
Overall Chronicity	=	# of animals with chronic disease divided by the # of animals
Overall Wastage	=	# of animals with chronic disease that didn't die divided by the #
		of animals
Overall Mortality	=	# of mortalities (all causes) divided by the # of animals
BRD Mortality	=	# of mortalities due to BRD divided by the # of animals
HS Mortality	=	# of mortalities due to histophilosis divided by the # of animals
Lameness Mortality	=	# of mortalities due to lameness divided by the # of animals
Metabolic Mortality	=	# of mortalities due to metabolic disease divided by the # of
·		animals
Other Mortality	=	# of mortalities (causes other than BRD, HS, lameness, or
		metabolic disease) divided by the # of animals
Production Variables		
Slaughter Weight	=	the total net live weight by multi-pen lots prior to slaughter
		divided by the # of animals sold and represents the average net
		live weight of animals sold for slaughter
Weight Gain	=	average slaughter weight minus the average initial weight and
		represents the average weight gain of animals sold for slaughter
Carcass Weight	=	total carcass weight at slaughter divided by the # of animals sold
		and represents the average carcass weight of animals sold for
		slaughter
Dressing Percentage	=	total carcass weight at slaughter divided by the total weight at
		slaughter expressed as a percentage
Days on feed	=	average slaughter date minus the average allocation date and
		represents the average # of days on feed of animals sold for
		slaughter
DMI	=	total quantity of feed consumed (100% dry matter basis) divided
		by the # of cattle days and represents the pounds of feed
		consumed per animal per day
Feedlot Performance Vo	ariable	
ADG ¹ –LWB ²	=	(total net slaughter weight plus total weight of animals shipped
		for salvage slaughter plus total weight of animals that died minus
1 2		total initial weight) divided by the # of animals days
ADG^1 – CAB^2	=	(total carcass weight divided by a fixed dressing percentage
		(60.0%) plus total weight of animals shipped for salvage
		slaughter plus total weight of animals that died minus total initial
1 2		weight) divided by the # of animal days
$G:F^1-LWB^2$	=	DMI divided by ADG – LWB
$G:F^1 - CAB^2$	=	DMI divided by ADG – CAB

UF is undifferentiated fever, NF is no fever, BRD is bovine respiratory disease, HS is lesions consistent *Histophilus somni* infection, BVD is bovine viral diarrhea, DMI is daily dry matter intake, ADG is average daily gain, G:F is gain to dry matter intake ratio.

² LWB is live weight basis and CAB is carcass-adjusted basis.

Table 2. Diet composition and chemical analyses of the total mixed rations fed in a study evaluating the effects of feeding high and low starch:NDF barley and 0 or 20% DDGS on feedlot cattle performance in western Canada

	LO	0W ¹	HIC	GH ¹
Item ³	0	20	0	20
Ingredient				
LOW barley	98.08	78.08	-	-
HIGH barley	-	-	98.08	78.08
DDGS	-	20.00	-	20.00
Supplement ⁴	1.92	1.92	1.92	1.92
Nutrient Composition, ⁵				
Number of samples ⁶	5	4	5	5
Dry Matter	87.7	87.9	87.0	87.0
CP	12.1	18.1	11.5	18.2
Ash	6.7	9.1	6.1	8.2
Fat	2.5	4.9	2.4	5.4
NDF	15.9	20.2	15.1	21
Starch	50.2	34.1	53.1	39.5
Phosphorus	0.34	0.44	0.32	0.46
Potassium	0.64	0.78	0.59	0.81

HIGH barley is barley that was segregated based on a high starch:NDF ratio (>3.25). LOW barley is barley that was segregated based on a low starch:NDF ratio (<3.25). Mean and SD for starch:NDF for HIGH and LOW was 3.48 ± 0.26 and 2.94 ± 0.25 , respectively.

² DDGS is corn based dried distillers grains with solubles. 0 is 0% DDGS and 20 is 20% DDGS included in the diet

^{3.} All numbers are expressed as percentages on a 100% DM basis.

^{4.} Supplement was manufactured at Landmark Feeds (Strathmore, AB) and included 27.6 mg/kg DM monensin (Rumensin, Elanco Animal Health, Indianapolis, Indiana), 12.1 mg/kg DM tylosin (Tylan, Elanco Animal Health), and 0.5 mg/heifer daily melengestrol acetate (MGA, Pfizer Animal Health, Kirkland, QC).

^{5.} Analyses performed by DairyOne, Ithaca, NY.

^{6.} One sample from the LOW/20 group was removed from the analyses due to low CP content.

Table 3. Growth performance and carcass characteristic data summary from a study evaluating the effects of feeding high and low starch:NDF barley and 0 or 20% DDGS on feedlot cattle performance in western Canada

	BAR	RLEY ¹	DDGS^2			P-Value			
Item	HIGH	LOW	0	20	SEM	BARLEY	DDGS	INT	
Average DOF	82	81	83	83	11.53	0.13	0.81	0.71	
Carcass Adjusted Perfo	rmance³								
Final BW, kg	584.2	589.8	586.5	587.5	2.5	0.03	0.70	0.46	
Weight Gain, kg	96.3	102.1	98.8	99.5	24.9	0.03	0.79	0.44	
DMI, kg/d	9.4	9.7	9.4	9.7	0.07	< 0.01	< 0.01	0.23	
ADG, kg	1.12	1.18	1.15	1.15	0.10	0.02	0.92	0.94	
G:F	0.111	0.114	0.123	0.119	0.01	0.25	0.12	0.72	
Live Performance ⁴									
Initial BW, kg	487.2	487.0	487.2	487.0	23.5	0.79	0.86	0.90	
Final BW, kg	584.9	589.0	587.7	586.1	2.8	0.06	0.46	0.19	
Weight Gain, kg	96.9	101.2	100.0	98.1	23.5	0.07	0.42	0.21	
ADG, kg	1.14	1.17	1.17	1.14	0.08	0.24	0.19	0.30	
G:F	0.113	0.113	0.125	0.117	0.01	0.85	0.01	0.19	
Carcass characteristics									
HCW, kg	341.8	345.2	343.3	343.8	1.5	0.03	0.74	0.45	
12 th Rib Fat, cm	1.17	1.14	1.14	1.19	0.03	0.28	0.02	0.22	
LM Area, cm ²	86.1	86.5	86.6	85.9	0.18	0.61	0.21	0.39	
Marbling Score ⁵	439	436	437	438	2.9	0.25	0.64	0.44	
Dressing %	58.44	58.59	58.39	58.64	0.19	0.53	0.28	0.71	

HIGH barley is barley that was segregated based on a high starch:NDF ratio (>3.25). LOW barley is barley that was segregated based on a low starch:NDF ratio (<3.25). Mean and SD for starch:NDF was 3.48 ± 0.26 for HIGH and 2.94 ± 0.25LOW. There were 5 replicates (16 pens) per treatment. 4,769 animals were allocated to HIGH and 4,778 to LOW.

^{2.} DDGS is corn based dried distillers grains with solubles. 0 is 0% DDGS included in the diet, 20 is 20% DDGS included in the diet. There were 5 replicates (16 pens) per treatment. A total of 4,766 animals were allocated to 0 and 4,781 to 20.

^{2.} Carcass Weight Basis values were calculated using carcass weights, converted to live weights using a fixed dressing % of 60.0%.

^{4.} Live Weight Basis values were calculated using shrunk live weights obtained prior to slaughter.

^{5.} Marbling Score 600=Modest, 500=Small, 400=Slight

Table 4. Yield and quality grade data summary from a study evaluating the effects of feeding high and low starch:NDF barley and 0 or 20% DDGS on feedlot cattle performance in western Canada

	BAl	RLEY ¹	DD	$DDGS^2$			P-Value	
Item	HIGH	LOW	0	20	SEM	BARLEY	DDGS	INT
USDA Yield Gro	ade							
1	17.22	17.23	18.30	16.15	1.26	0.99	0.07	0.39
2	39.64	39.73	40.83	38.55	1.57	0.94	0.06	0.26
3	33.35	34.17	32.62	34.91	1.83	0.45	0.04	0.96
4	9.00	8.33	7.54	9.80	1.03	0.41	< 0.01	0.84
5	0.79	0.52	0.71	0.59	0.19	0.18	0.537	0.25
USDA Quality C	Grade							
Prime	0.04	0.06	0.02	0.08	0.04	0.69	0.26	0.22
Choice	21.51	20.65	20.64	21.51	1.23	0.48	0.48	0.45
Select	43.42	42.84	43.03	43.25	1.19	0.61	0.85	0.72
Standard	35.03	36.45	36.31	35.16	1.64	0.38	0.48	0.38

HIGH barley is barley that was segregated based on a high starch:NDF ratio (>3.25). LOW barley is barley that was segregated based on a low starch:NDF ratio (<3.25). Mean and SD for starch:NDF for HIGH and LOW was 3.48 ± 0.26 and 2.94 ± 0.25 , respectively.

² DDGS is corn based dried distillers grains with solubles. 0 is 0% DDGS included in the diet, 20 is 20% DDGS included in the diet.

^{3.} All numbers are expressed as percentages.

Table 5. Morbidity and mortality data summary from a study evaluating the effects of feeding high and low starch:NDF barley and 0 or 20% DDGS on feedlot cattle performance in western Canada

	BAR	LEY ¹	DD	GS^2			P-V	alue
Item ³	HIGH	LOW	0	20	SEM	BARLEY	DDGS	INT
<i>Morbidity</i> ⁴								
First UF Treatment	0.00	0.04	0.00	0.04	0.02	0.13	0.13	0.12
First NF Treatment	0.00	0.08	0.04	0.04	0.03	0.02	0.98	0.99
First AIP Treatment	0.21	0.11	0.15	0.17	0.07	0.14	0.77	0.27
First AR Treatment	0.21	0.30	0.20	0.32	0.08	0.34	0.22	0.95
First Bloat Treatment	0.08	0.00	0.06	0.02	0.03	0.03	0.26	0.25
First Lameness Treatment	0.19	0.45	0.26	0.39	0.15	0.22	0.53	0.73
Chronicity	0.14	0.31	0.17	0.28	0.13	0.15	0.33	0.58
Wastage	0.14	0.26	0.17	0.23	0.11	0.19	0.46	0.82
<i>Mortality</i> ⁴								
Overall Mortality	0.36	0.45	0.37	0.45	0.10	0.52	0.58	0.53
BRD Mortality	0.07	0.07	0.09	0.05	0.04	0.90	0.40	0.86
Lameness Mortality	0.00	0.09	0.05	0.04	0.03	0.04	0.88	0.88
Metabolic Mortality	0.15	0.30	0.21	0.23	0.06	0.11	0.82	0.79
Miscellaneous Mortality	0.22	0.07	0.11	0.17	0.07	0.10	0.46	0.50

HIGH barley is barley that was segregated based on a high starch:NDF ratio (>3.25). LOW barley is barley that was segregated based on a low starch:NDF ratio (<3.25). Mean and SD for starch:NDF for HIGH and LOW was 3.48 ± 0.26 and 2.94 ± 0.25 , respectively.

^{2.} DDGS is corn based dried distillers grains with solubles. 0 is 0% DDGS included in the diet, 20 is 20% DDGS included in the diet.

^{3.} All numbers are expressed as percentages.

^{4.} UF is undifferentiated fever, NF is no fever, AIP is atypical interstitial pneumonia, AR is arthritis, and BRD is bovine respiratory disease.

Table 6. Chemical analyses of manure samples from a study evaluating the effects of feeding high and low starch:NDF barley and 0 or 20% DDGS on feedlot cattle performance in western Canada

	BAR	LEY ¹	$DDGS^2$				P-	value
Nutrient ^{3,4}	HIGH	LOW	0	20	SEM	Barley	DDGS	Interaction
Number of Samples ⁵	32	32	32	32	-	-	-	-
DM Removed, kg/heifer	258.6	297.9	317.6	322.7	47.40	0.18	0.47	0.58
Dry Matter	53.88	55.58	54.52	54.94	1.16	0.16	0.19	0.22
Organic Matter	23.68	23.65	23.42	23.91	0.56	0.97	0.54	0.38
Nitrogen	0.87	0.89	0.86	0.90	0.02	0.50	0.25	0.21
Phosphorus	0.44	0.44	0.42	0.46	0.01	0.92	0.02	0.27
Calcium	2.33	2.36	2.34	2.35	0.08	0.84	0.95	0.14
Potassium	0.62	0.64	0.61	0.65	0.02	0.41	0.11	0.22
Starch	0.20	0.26	0.26	0.20	0.03	0.15	0.19	0.34

HIGH barley is barley that was segregated based on a high starch:NDF ratio (>3.25). LOW barley is barley that was segregated based on a low starch:NDF ratio (<3.25). Mean and SD for starch:NDF for HIGH and LOW was 3.48 ± 0.26 and 2.94 ± 0.25 , respectively.

^{2.} DDGS is corn based dried distillers grains with solubles. 0 is 0% DDGS included in the diet, 20 is 20% DDGS included in the diet.

^{3.} All numbers are expressed as percentages on a 100% dry matter basis.

^{4.} Chemical analyses were performed by Dairy One, Ithaca, New York.

^{5.} Two composites were formed using 20 subsamples for each composite. Subsamples were collected as manure was scraped into a pile in the middle of the pen. Both composites were submitted for analysis and the average of the two composites was used in the analysis.

Table 7. Nitrogen mass balance from a study evaluating the effects of feeding high and low starch:NDF barley and 0 or 20% DDGS on feedlot cattle performance in western Canada

		Treat	ment ¹		_	P-Value		
Item ³	HIGH/0	HIGH/20	LOW/0	LOW/20	SEM	BARLEY	DDGS	INT
Average days	82	81	83	83	11.53	0.13	0.81	0.71
Intake	17.1 ^a	27.4 ^b	19.1 ^a	26.2	1.47	0.62	< 0.01	0.04
Retention ⁴	2.1	2.1	2.1	2.2	0.48	0.03	0.28	0.35
Excreted ⁵	15.1 ^a	25.4 ^b	16.9 ^a	24.0 ^b	1.05	0.70	< 0.01	0.03
Removed ⁶	2.3	2.6	2.7	3.0	0.43	0.17	0.34	0.98
Loss	12.7 ^a	$22.8^{\mathrm{b,d}}$	$14.2^{a,b}$	21.0 ^{b,c}	0.78	0.83	< 0.01	0.02
Loss, %	84.18	89.44	81.98	87.67	1.90	0.19	< 0.01	0.88

HIGH barley is barley that was segregated based on a high starch:NDF ratio (>3.25). LOW barley is barley that was segregated based on a low starch:NDF ratio (<3.25). Mean and SD for starch:NDF for HIGH and LOW was 3.48 ± 0.26 and 2.94 ± 0.25 , respectively.

^{2.} DDGS is corn based dried distillers grains with solubles. 0 is 0% DDGS included in the diet, 20 is 20% DDGS included in the diet.

^{3.} All numbers are expressed on a kg/animal basis

^{4.} Retention is retention in the animal calculated from NRC equations (NRC, 1996)

⁵. Excreted is calculated as the difference between intake and retention

^{6.} Removed is the waste material removed from feedlot surface when pens were cleaned after all animals had been shipped for slaughter

^{7.} Runoff is included in the loss and is less than 5% of the total N loss

Table 8. Phosphorus mass balance from a study evaluating the effects of feeding high and low starch:NDF barley and 0 or 20% DDGS on feedlot cattle performance in western Canada

		Treat	ment ¹		P-Value			
Item ³	HIGH/0	HIGH/20	LOW/0	LOW/20	SEM	BARLEY	DDGS	INT
Average days	82	81	83	83	11.53	0.13	0.81	0.72
Intake	2.9°	4.4 ^a	3.3 ^b	4.3°	0.53	0.18	< 0.01	0.03
Retention ⁴	0.5	0.5	0.5	0.5	0.26	0.03	0.28	0.37
Excreted ⁵	2.2°	3.4 ^a	2.5 ^b	3.5 ^a	0.78	0.20	< 0.01	0.05
Removed ⁶	1.1	1.3	1.3	1.5	0.45	0.21	0.15	0.98
Loss	1.1	2.0	1.2	2.0	0.65	0.69	< 0.01	0.16
Loss, %	45.79	58.52	45.15	56.62	7.51	0.62	< 0.01	0.71

HIGH barley is barley that was segregated based on a high starch:NDF ratio (>3.25). LOW barley is barley that was segregated based on a low starch:NDF ratio (<3.25). Mean and SD for starch:NDF for HIGH and LOW was 3.48 ± 0.26 and 2.94 ± 0.25 , respectively.

² DDGS is corn based dried distillers grains with solubles. 0 is 0% DDGS included in the diet, 20 is 20% DDGS included in the diet.

^{3.} All numbers are expressed on a kg/animal basis

^{4.} Retention is retention in the animal calculated from NRC equations (NRC, 1996)

⁵ Excreted is calculated as the difference between intake and retention

Removed is the waste material removed from feedlot surface when pens were cleaned after all animals had been shipped for slaughter

^{7.} Runoff is included in the loss and is less than 5% of the total P loss

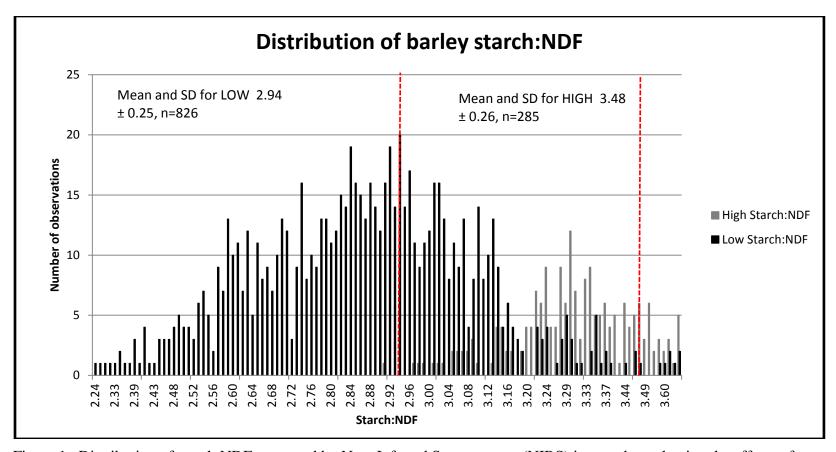


Figure 1. Distribution of starch:NDF measured by Near Infrared Spectroscopy (NIRS) in a study evaluating the effects of feeding high and low starch:NDF barley and 0 or 20% DDGS on feedlot cattle performance in western Canada

HIGH barley is barley that was segregated based on a high starch:NDF ratio (>3.25). LOW barley is barley that was segregated based on a low starch:NDF ratio (<3.25).

CHAPTER IV: NUTRIENT MASS BALANCE AND FEEDLOT PERFORMANCE OF FEEDLOT CATTLE FED BARLEY BASED DIETS WITH DIFFERENT LEVELS OF MONENSIN

E. M. Hussey*[‡], G.E. Erickson*, R.E. Peterson[‡], L.O. Burciaga-Robles[‡], and M.L. May[‡]

*Department of Animal Science, University of Nebraska, Lincoln 68583, [‡]Feedlot Health

Management Services Ltd., Okotoks, Alberta, Canada T1S 2A2

Abstract

Crossbred heifer calves (n=9,617, 32 pens, 269 ± 6 kg initial BW, days on feed=229) were assigned randomly at feedlot arrival to a 2 x 2 factorial arrangement of treatments. Main effects included LOW or HIGH starch:neutral detergent fiber (NDF) barley and 25 or 48mg/kg inclusion of monensin. Barley was determined to be HIGH (starch:NDF > 3.25) or LOW (starch:NDF < 3.25) at feedlot arrival based on values determined by Near Infrared Spectroscopy. The objective was to evaluate the impact of HIGH or LOW barley and 25 or 48mg/kg monensin (25RUM or 48RUM) on feedlot performance, carcass characteristics and nutrient mass balance. No barley x monensin interactions were observed when performance data were analyzed. Intake, ADG, carcass weight, 12th rib fat, and marbling score were greater (P<0.01) for LOW, but G:F was not different (P≥0.24). Percentage of carcasses grading choice was greater (P<0.01) for LOW compared to HIGH. Feeding LOW barley decreased (P<0.01) the percentage of YG 2 carcasses, increased (P<0.01) YG 3 carcasses. Intake, ADG, HCW, dressing %, and 12th rib fat were greater (P<0.01) for 25RUM, but G:F was not different ($P\ge0.30$). Percentage of YG 3 and YG 4 carcasses were greater ($P \le 0.03$) for and percentage of YG 1 carcasses

was decreased (P=0.01) for 25RUM. Barley x monensin interactions were observed for N intake and excretion (P<0.01) and for P intake and P excretion (P=0.04). Nitrogen intake was greatest (P<0.01) for LOW/48RUM at 50.0 kg, 49.3 kg for LOW/25RUM, 49.4 for HIGH/48RUM, and 47.0 for HIGH/25RUM. Retention of N (P<0.01) was greater for LOW and for 25RUM. Excretion of N was greatest (P<0.01) for LOW/48RUM at 44.1 kg, 43.3 kg for HIGH/48RUM, 43.2 kg for LOW/25RUM, and 41.0 kg for HIGH/25RUM. Intake of P was greatest (P<0.01) for LOW/48RUM at 11.1 kg, 10.9 kg for LOW/25RUM and HIGH/48 RUM, and 10.4 kg for HIGH/25RUM. Excretion of P per heifer was greatest (P<0.01) for LOW/48RUM at 9.7kg, 9.5kg for HIGH/48RUM, 9.3 kg for LOW/25RUM, and 9.1 kg for HIGH/25RUM. Removal of DM, N, and P in manure, and N and P losses were not affected (P≥0.19) by barley starch:NDF or monensin level. Feeding LOW starch:NDF barley and 25RUM improved feedlot performance and carcass characteristics, with minimal effects on nutrient management

Key words: barley, monensin, mass balance

Introduction

Barley is a major cereal grain used for feeding cattle in Western Canada and the Pacific Northwest. Previous in-house research segregating barley using Near Infrared Spectroscopy (NIRS) based on a digestible energy calculation into high and low energy barley and feeding high, low, or a 50:50 blend of the two (Hussey et al., 2012). Overall mortality increased by increasing NIRS predicted barley energy, most of which were metabolic and miscellaneous. However, G:F on an adjusted carcass weight basis was improved for the low energy barley. Results of this trial did not support the original

hypothesis that greater DE content of barley would improve performance, indicating that additional research was needed to better understand NIRS as a tool for feed commodity valuation. Based on animal performance, morbidity/mortality, and carcass characteristics from this initial trial, a follow up study was designed using starch:neutral detergent fiber (NDF) ratio to more accurately identify barley that was considered to be high risk for affecting animal performance and morbidity/mortality.

Monensin (Rumensin®, Elanco Animal Health, Indianapolis, IN) is an ionophore commonly fed to feedlot cattle to improve feed efficiency (Richardson et al., 1976; Goodrich et al., 1984). Ionophores may enhance the efficiency of ruminal fermentation by shifting microbial profiles (Bergen and Bates 1984), stabilizing ruminal pH (Nagaraja et al. 1982), and reducing feed intake variation (Burrin et al., 1988; Cooper et al., 1997; Stock et al., 1995). If feeding high energy barley imposes a greater risk of digestive disturbances than feeding low energy barley (Hussey et al., 2012) then increasing dietary monensin concentration may be beneficial in barley based diets. No research has been done evaluating the effects of monensin concentration on nutrient mass balance. Thus, the objective of this study was to evaluate the impact of HIGH or LOW barley and 25 or 48 mg/kg monensin on feedlot performance, carcass characteristics, and N and P mass balance in commercial sized pens.

Materials and Methods

All procedures involving live animals were approved by the Feedlot Health

Management Services Ltd. (FHMS) Animal Care and Use Committee with informed

consent from the animal owners.

Study Facilities

The study was conducted at Western Feedlots Ltd.- High River, a commercial feedlot near High River, AB, Canada. The cattle were housed in standard facilities for western Canada including open-air, dirt-floor pens with central feed alleys and 20% porosity wood-fence windbreaks. Animal handling facilities had a hydraulic chute equipped with an individual animal scale, a chute-side computer with individual animal data collection, management software (*i*FHMS, Feedlot Health Management Services Ltd., Okotoks, AB, Canada) and separation alleys to facilitate the return of animals to designated pens.

Study Animals

At the time of feedlot arrival, each animal was individually weighed (scale model LS51208, Cardinal Scale Manufacturing Co. Webb City, MO) and received health and production products as per standardized commercial feedlot practices which included individual animal identification, an infectious bovine rhinotracheitis (IBR) virus, parainfluenza-3 (PI₃) virus, bovine viral diarrhea (BVD) virus (types I and II) and bovine respiratory syncytial virus combination vaccine, a *Mannheimia haemolytica* toxoid (Pyramid 5 +Presponse® Boehringer Ingelheim Animal Health, Boehringer Ingelheim Canada Ltd., Burlington, ON), a *Clostridium chauvoei, septicum, novyi, sordellii*, *perfringens* Types B, C and D and *Histophilus somni* bacterin-toxoid (Ultrabac

7/Somubac®, Pfizer Animal Health), topical ivermectin for gastrointestinal and external parasite control (Normectin® Pour-On Solution, Norbrook Pharmaceuticals, Lenexa, KS (1 mL/10 kg BW)), an intramuscular (IM) prostaglandin for termination of pregnancy (Lutalyse®, Pfizer Animal Health), and IM tulathromycin (Draxxin®, Pfizer Animal Health, Pfizer Inc., Kirkland, QC). Body weight and hip height were recorded for each animal and each animal was given a numbered visual identification tag. After treatment assignment, all heifers received a delayed implant at approximately 35 days on feed (Synovex Choice®, Pfizer Animal Health), and an infectious bovine rhinotracheitis (IBR) virus, parainfluenza-3 (PI₃) virus, and bovine viral diarrhea (BVD) virus (types I and II) (Bovi-Shield® Gold 4, Pfizer Animal Health). At day 125, all animals were rehandled and were given an implant (Synovex Choice®, Pfizer Animal Health, and an infectious bovine rhinotracheitis (IBR) virus, parainfluenza-3 (PI₃) virus, and bovine viral diarrhea (BVD) virus (types I and II) (Bovi-Shield® Gold 4, Pfizer Animal Health).

Experimental Design

Crossbred yearling heifers (n=9,617, 269 ± 6 kg initial BW, days on feed=229) were assigned randomly at the time of feedlot arrival to a 2 x 2 factorial arrangement of treatments and fed for an average of 229 d from October, 2010 to July, 2011 at Western Feedlots Ltd.-High River, a commercial feedyard near High River, AB, Canada. All cattle were individually weighed (scale model LS51208, Cardinal Scale Manufacturing Co. Webb City, MO) at the time of allocation (Model LS51208, Cardinal Scale Manufacturing Co. Webb City, MO). The factors included LOW or HIGH starch:NDF barley and 25 or 48 mg/kg inclusion of monensin, for a total of 8 pens per treatment and

4 treatments. . Study animals were housed by experimental group in commercial feedlot pens and followed from allocation until slaughter.

Barley was determined to be HIGH (starch:NDF > 3.25) or LOW (starch:NDF < 3.25) at feedlot arrival based on values determined by NIRS. The cutoff value of 3.25 resulted in one third of the barley that arrived at the feedlot would be HIGH starch:NDF barley (Figure 1). In some instances, the cutoff for HIGH vs LOW starch:NDF barley had to be adjusted based on starch:NDF of barley arriving at the feedlot to ensure that enough barley was available to feed study cattle. Thus, starch:NDF ratio was 3.15 ± 0.16 for HIGH, and 2.80 ± 0.19 for LOW. Dietary starch content was 34.86% for LOW/25, 32.17% for LOW/48, 35.71% for HIGH/25, and 32.93% for HIGH/48. Dietary NDF content was 20.16% for LOW/25, 20.89% for LOW/48, 19.73% for HIGH/25, and 20.72% for HIGH/48. Once a shipment of barley was determined to be HIGH or LOW, it was tempered to 18.5% moisture, rolled, and stored by barley treatment. A surfactant (Grain Prep Processing Aid, Agri Chem, Inc., Ham Lake, MN) was also added to the barley at time of processing.

Complete feedlot diets and nutrient analysis results are presented in Table 2.

Diets were formulated to meet or exceed the National Research Council (NRC, 1996)

nutritional requirements for beef cattle and were offered *ad libitum* throughout the feeding period. Water was also supplied *ad libitum*. Feedlot diets were blended in truckmounted mixer boxes (Cattlelac, Reg Cox Feed Mixers Inc., Red Deer, AB Canada) equipped with electronic load cells. Diets were delivered to the pens once daily at 0700 and daily feed allowances to each pen were recorded using the feedlots administrative

software (Feedback, ComputerAid Professional Services Ltd., Okotoks, AB). Rations and ration changes associated with step up to the finishing diet were based on commercial feedlot protocols, and occurred on the same day within each replicate.

Animals received pulse dose feeding regimes of CTC in accordance with the standard CTC feeding program for the control of *Histophilus somni* (HS) during the first part of the feeding period. A pulse was defined as five consecutive days of CTC (Aureomycin® 220 G, Alpharma Canada Corporation, Mississauga, ON) at a dosage of 1 g CTC/45 kg BW/animal/day. Study animals were conditioned to a high concentrate diet composed of approximately 78% barley, 20% corn-based dried distillers grains plus solubles (DDGS), and 1.92% supplement on a DM basis over a 20 to 28 day period. Rumensin was included in the supplement to provide either 25 or 48 mg/kg. The supplement included in the ration was manufactured at a commercial feed mill (Landmark Feeds, Strathmore, AB). Tylosin was included in the diet at 12.1 mg/kg DM (Tylan®, Elanco Animal Health) and melengestrol acetate was included at 0.5 mg/heifer daily (MGA®, Pfizer Animal Health).

Feedbunk samples were collected twice monthly. For each pen, equal sized feed samples were collected from the beginning, middle, and end of the bunk. On each sampling day, samples from each pen in an experimental group were composited to form one sample for each experimental group. Samples were frozen until the end of the study. Samples were submitted to a commercial lab (DairyOne, Ithaca, NY) for DM (Georing and Van Soest, 1970), crude protein (CP, AOAC 990.03), ash (AOAC Method 942.05), fat (AOAC 2003.05), NDF (solutions as in Van Soest, P.J, methods as in ANKOM

Technology Method 6), starch, P, and potassium (K). For P and K, samples were predigested at ambient temperature 15 minutes with 8ml nitric acid (HNO₃) and 2ml hydrochloric acid (HCl) then ramped to 190°C in 15 minutes and finally held at digestion temperature of 190°C for 15 minutes at 1600W. Vessels brought to 50-ml volume aliquot used for analysis. Samples were snalyzed using an Intrepid Inductively Coupled Plasma (ICP) Radial Spectrometer after microwave digestion (CEM Application Note for Acid Digestion, Matthews, NC) (Wolf et al., 2003). Starch samples were pre-extracted for sugar by incubation in 40°C water bath and filtration on Whatman 41 filter paper. Residues were thermally solubilized using an autoclave, and then incubated with glucoamylase enzyme to hydrolyze starch to produce dextrose (glucose). Prepared samples were injected into a sample chamber of YSI Analyzer where dextrose diffuses into a membrane containing glucose oxidase. The dextrose was immediately oxidized to hydrogen peroxide and D-glucono-4-lactone. The hydrogen peroxide is detected amperometrically at the platinum electrode surface. The current flow at the electrode is directly proportional to the hydrogen peroxide concentration, and hence to the dextrose concentration. Starch was determined by multiplying dextrose by 0.9 (YSI Incorporated Life Sciences, Yellow Springs, OH).

Animal Health and Marketing

Experienced animal health personnel that were blinded to the experimental status of each pen observed the study animals once daily for evidence of disease. Animals deemed to be "sick" by the animal health personnel, based on subjective criteria such as general appearance, attitude, gauntness, reluctance to move, etc., were individually sorted from pen mates, moved to the hospital facility, diagnosed, and treated as per the standard

feedlot protocol. The treatment events including the treatment date, the presumptive diagnosis, drug(s) administered, and dose(s) used were recorded.

The case definition for undifferentiated fever (UF) was a lack of abnormal clinical signs referable to body systems other than the respiratory system, a rectal temperature ≥ 40.6°F, and no previous treatment history. The case definition for no fever (NF) was a lack of abnormal clinical signs referable to body systems other than the respiratory system, a rectal temperature < 40.6°F, and no previous treatment history for UF. Animals identified as "sick" subsequent to the third relapse therapy for each disease in the treatment protocol were deemed to be "chronics". Also, animals that were unsuitable to be returned to their designated feedlot pens, based on subjective appraisal of the attitude and appearance of each animal, were deemed to be "chronics". Chronics that did not die during the study were defined as wastage. Chronics and wastage were included in the performance calculations, described in Table 1.

A gross necropsy examination was performed on each animal that died during the study period by trained personnel from Feedlot Health Management Services Ltd. (FHMS). All animals that died were weighed by feedlot personnel. Animals that died as a result of bovine respiratory disease (BRD) were classified as BRD mortalities. Animals that died as a result of lesions consistent with *Histophilus somni* (HS) infection were classified as HS mortalities. Animals that died as a result of lameness (arthritis, foot rot, or foot lesions) were classified as lameness mortalities, and animals that died as a result of metabolic disease (atypical interstitial pneumonia, bloat, chronic rumenitis, enterotoxemia, laminitis, liver abscesses, overload, or posterior vena cava thrombosis)

were classified as metabolic mortalities. Animals that died of miscellaneous causes (causes other than causes other than BRD, HS, lameness, or metabolic disease) were classified as miscellaneous mortalities. Overall mortality is the sum of all mortalities throughout the study period. Weights of animals that died or were shipped for salvage slaughter during the study were included in the performance calculations.

At the end of the feeding period, heifers were shipped for slaughter according to BW strata identified at reimplant. Ultra-heavy and heavy heifers at the time of reimplant were shipped for slaughter first, followed by middle weight heifers, and then light weight heifers. All cattle were slaughtered at the same commercial packing plant (Cargill, High River, AB) and approximately the same number of animals per treatment within a replicate were shipped for harvest on a given day. Carcass weight, fat thickness, LM area, marbling score, USDA Quality Grade (QG), and USDA Yield Grade (YG) were recorded at the packing plant.

Nutrient Balance

Nutrient mass balance was conducted using 32 open-air feedlot pens with 8 pens per treatment. Since the feedlot where the study was conducted was a large commercial yard, runoff from the 32 pens was not separated from runoff from the rest of the feedlot. Previous research indicates that runoff represents less than 5% of the total nutrient loss (Quinn et al., 2007; Luebbe et al., 2009; Rich et al., 2011) and was therefore assumed in the nutrient losses. Pens were cleaned prior to allocation of animals to the trial. Once all of the heifers in a pen had been shipped for harvest, pens were cleaned by scraping manure into a pile in the middle of the pen and loaded into a tractor-trailer using a loader tractor. Trucks hauling manure were weighed using an 80 ton scale (model 777, Cardinal

Scale Manufacturing Co. Webb City, MO) and the total wet weight was recorded by pen. Two composite manure samples were taken as the pile was hauled out of the pen by collecting 20 sub-samples. Composites were submitted to Agri-Food Laboratories (Guelph, ON, Canada) for nutrient analysis. All samples were analyzed for DM (Helrich, K., and Padmore, J.M. 1990), organic matter (OM, AOAC method 967.05), N (AOAC method 990.03); P, Ca, K (AOAC method 985.01), pH, and starch (AOAC method 996.11).

Feedbunks and feed ingredients were sampled every 2 weeks to determine nutrient intake by pen. Retained heifer N and P were calculated using energy, protein, and P equations (NRC, 1996). Nutrient excretion was determined by subtracting nutrient retention from intake (ASABE, 2005). Total N lost (kg/heifer) was calculated by subtracting manure N from excreted N. Percentage of N lost was calculated as N lost divided by N excretion. Total P lost (kg/heifer) was calculated by subtracting manure P from excreted P. Percentage of P lost was calculated as P lost divided by P excretion.

Statistical Analysis

All data were analyzed using the GLIMMIX procedure of SAS (SAS® for Windows, Release 9.2, SAS Institute Inc., Cary, NC). Treatment was included in the model as fixed effects and replicate was included as a random effect. Pen served as the experimental unit. When feedbunk sample results were analyzed, experimental group was included in the model as fixed effect and week sampled was included as a random effect. For each variable, interactions between barley type and monensin concentration were tested. If no interaction was observed, the interaction term was removed from the

model and the main effects were evaluated. Overall *P*-values were derived from the *F*-test for treatment and comparison and *P*-values were differences of the least square means using p-diff. The α level for all analyses was ≤ 0.05 .

Results and Discussion

Feedlot Performance

Feedlot performance data are presented in Table 3. No interactions were observed when performance data were analyzed, therefore only main effects are presented. Daily dry matter intake was 0.2 kg greater (P<0.01) for LOW starch:NDF barley, with the heifers fed LOW barley consuming 7.5 kg and heifers fed HIGH barley consuming 7.3 kg. On a live and on a carcass adjusted basis, ADG was greater (P<0.01) for LOW compared to HIGH. Feed efficiency however, was not different (P≥0.24), and was on average 0.143 on a live weight basis, and 0.149 on a carcass weight basis.

Starch is the primary nutrient of ruminant diets used to promote high levels of production (Theurer, 1986). However, the major site of barley starch digestion is in the rumen, therefore rapid consumption of high grain diets can increase the risk of acidosis (Fulton et al., 1979 and Stock et al., 1990) and have negative effects on cattle performance. In the present study, no differences in feed efficiency were observed, but intake and ADG were greater for heifers fed LOW barley compared to HIGH.

Acute and chronic acidosis, conditions that follow ingestion of excessive amounts of readily fermented carbohydrate, are prominent production problems for ruminants fed diets rich in concentrate (Owens et al., 1998). The primary symptom of subacute acidosis is reduced and erratic feed intake (Cooper et al., 1999) lending to lower ADG with either

no effect or increases in G:F. . Stock et al. (1990) notes than during acidosis, rumen pH declines, and cattle adjust by decreasing DM intake. However, Owens et al. (1998) reported that even after animals recover from a bout of acidosis, nutrient absorption may be retarded. The findings of the present study are consistent with Stock et al. (1990), as the heifers fed HIGH barley had lower daily DMI than heifers fed LOW starch:NDF barley. The reduced intake may be amplified due to the lack of roughage in the finishing ration in this study (Stock et al., 1990). Based on the improvements in feedlot performance with LOW starch:NDF barley compared to HIGH, this doesn't seem to be the case in the present study.

Intake was 0.2 kg per day greater (P<0.01) for heifers fed 25RUM compared to 48RUM. Heifers fed 25RUM consumed 7.5 kg per day; whereas heifers fed 48RUM consumed 7.3 kg per day. Fulton et al. (1978a and 1978b) observed that reduced ruminal pH was closely related to a reduction in feed intake in cattle adjusted to ration containing 90% rolled wheat. Monensin supplemented cattle have higher rumen pH (Nagaraja et al., 1981 and 1982), and therefore may limit reductions in intake when high concentrate rations are fed. Reduced intake is commonly reported when monensin is fed to feedlot cattle, especially immediately following introduction (Spires et al. 1990; Galyean et al. 1992). Raun et al. (1976) conducted a study to define the dose response relationships between 0, 2.7, 5.5, 11, 22, 33, 44 and 88 mg/kg monensin on performance. Similar to the present study and the results of Boling et al. (1977), the authors found that feed consumption decreased progressively, with increasing monensin dosage.

Heifers fed 25RUM had greater (P<0.01) ADG on both a live and carcass-adjusted basis compared to 48RUM. Response in ADG to monensin supplementation is variable (Boling et al., 1977). Erickson et al. (2003) conducted four different experiments to compare traditional bunk management and clean bunk management strategies on steer performance, feeding behavior, and ruminal fermentation, and to determine whether dietary monensin concentration alters cattle and ruminal responses to clean bunk management systems. In contrast to the results of the present study, those authors did not observe a difference in ADG when steers were fed 28.6 or 36.3 mg/kg monensin. Boling et al. (1977) fed 0, 25, 50, or 100 mg monensin per head and reported an improvement in ADG at 50 and 100 mg monensin, but these levels are considerably lower than what was fed by Erickson et al. (2003) and in the present study.

In the present study, G:F was not affected (P≥0.30) by monensin level when calculated on a live or on a carcass adjusted basis. Feed efficiency response to monensin supplementation has also been variable, but an improvement is often observed. Stock et al. (1995) evaluated 0, 22, or 33 mg/kg in four feedlot experiments. Feeding monensin improved feed efficiency by 4%; but no differences were detected between 22 and 33 mg/kg monensin treatments. Erickson et al. (2003) observed that feed efficiency was not markedly influenced when monensin was increased from 28.6 to 36.3 mg/kg (DM basis) in four experiments. In contrast, in their study with increasing monensin concentration, Raun et al. (1976) observed improvements in feed efficiency for all levels of monensin compared to the negative control. However, in that study diets contained roughage, whereas the present study did not. Goodich et al. (1984) reported that as the energy density of the diet increases, feed conversion response to monensin supplementation

decreases. It is possible that the energy density of the all-concentrate rations was above the threshold where a response could be observed.

Carcass Characteristics

Carcass characteristics are presented in Table 3 and USDA yield and quality grade data are presented in Table 4. Carcass weight, 12th rib fat, and marbling score were greater (P<0.01) for heifers fed LOW starch:NDF barley. Carcasses from heifers fed LOW were 4 kg heavier than carcasses from heifers fed HIGH. Percentage of carcasses grading choice was greater (P<0.01) and percentage grading standard was decreased (P<0.01) for LOW. Feeding LOW starch:NDF barley decreased (P<0.01) the percentage of YG 2 carcasses, increased (P<0.01) the percentage of YG 3 carcasses likely due to improvements in ADG.

Carcass weight, dressing percentage, and 12th rib fat were greater (P<0.01) for 25RUM compared to 48RUM. In experiments two of four, Erickson et al. (2003) did not observe a difference in carcass weight between steers fed 28.6 or 36.3 mg/kg monensin. Carcasses from heifers fed 25RUM were 4.6 kg heavier than carcasses from heifers fed 48RUM. Longissimus muscle area and marbling score were not affected (P≥0.21) by monensin level. Percentage of YG 3 and YG 4 carcasses were greater (P≤0.03) and percentage of YG 1 carcasses was decreased (P=0.01) for 25RUM. In contrast, Erickson et al. (2003) in experiment two of four, reported that feeding a higher concentration (36.3 mg/kg) of monensin increased the percentage of YG3 carcasses, whereas feeding a lower concentration (28.6 mg/kg) of monensin tended to increase the percentage of YG 2. Erickson et al. (2003) in experiment one of four observed an increase in the percentage of

YG 1 carcasses when 28.6 mg/kg monensin was fed. The percentage of carcasses grading prime, choice, or select was not different (P≥0.11) between the two monensin levels. In contrast, Erickson et al. (2003) observed a decrease (P=0.03) in the percentage of carcasses grading choice when the higher level of monensin was fed.

Animal Health

Animal health data are presented in Table 5. No barley x monensin interactions were observed when animal health data were analyzed. Barley did not have an effect on morbidity or mortality outcomes. The number of animals pulled and treated for UF, NF, or bloat was not different ($P \ge 0.20$). Similarly, the number of animals defined as chronics or as wastage was not affected ($P \ge 0.19$) by barley treatment. No difference ($P \ge 0.18$) was observed in the number of animals that died as a result of BRD, lameness, or metabolic disease. Overall mortality was also similar (P = 0.79). However, the number of animals that died as a result of miscellaneous causes was greater (P = 0.03) for heifers fed LOW starch:NDF barley compared to HIGH.

Monensin concentration had no effect (P≥0.56) on the number of animals pulled and treated for UF or NF, and no effect (P=0.26) on the number of animals classified as chronics. However, feeding 48RUM increased (P=0.02) the number of animals defined as wastage (chronics that did not die). The number of animals that died as a result of BRD or lameness was not different (P≥0.51). Overall mortality was also similar (P=0.13) between the groups fed different concentrations of monensin. The number of miscellaneous mortalities tended (P=0.08) to be greater for 25MG/KG. Although the number of metabolic mortalities was not significantly different (P=0.11), it is possible

that the study cattle were not on feed long enough to realize a significant difference. Final live weights were only, on average, 516.7 ± 1.68 kg, so it is possible that any metabolic mortalities that typically occur late in the feeding period were absent because study animals were not fat enough at time of slaughter. Metabolic and digestive disorders account for 25.9% of deaths in beef cattle and occur later in the feeding period (Smith, 1998).

Nutrient Balance

Manure nutrient composition data are presented in Table 6. No barley x monensin interactions were observed when manure nutrient composition data were analyzed. Barley starch:NDF ratio had no effect (P≥0.11) on manure DM, OM, N, P, Ca, K, or starch. Monensin level did not have an effect (P≥0.12) on manure OM, P, K, or starch content. Pens of cattle fed 25RUM produced manure with a lower (P=0.02) DM content than pens of cattle fed 48RUM.

Kissinger et al. (2007) used data from 6 commercial feedlots (representing 6,366 head of cattle) and observed significant variation among feedlots. The authors hypothesized that the variation is driven by ration nutrient concentration (P only), pen conditions prior to and during manure harvest (N and P), and management choices relative to use of manure in lot maintenance (N and P). The difference in P content of manure in the present study was due to the main effect of barley starch:NDF. Kissinger et al. (2007) also suggested that 33% of excreted N (65 g/animal daily) and 91% of excreted P (32 g/animal daily) are harvested as manure on average.

Nutrient balance data are presented in Table 7 and Table 8. When N balance data were analyzed, two barley x monensin interactions (P<0.01) were observed. The first interaction (P<0.01) was observed when N intake was analyzed. Nitrogen intake per heifer was greatest (P<0.01) for LOW/48RUM at 50.0 kg, 49.3 kg for LOW/25RUM, 49.4 for HIGH/48RUM, and 47.0 for HIGH/25RUM. Differences in N intake were due to the differences in DM intake. Retention of N per heifer was 0.1 kg greater (P<0.01) for heifers fed LOW compared to HIGH. The second interaction (P<0.01) was observed when N excretion was analyzed. Excretion of N per heifer was greatest (P<0.01) for LOW/48RUM at 44.1 kg, 43.3 kg for HIGH/48RUM, 43.2 kg for LOW/25RUM, and 41.0 kg for HIGH/25RUM. Removal of DM and N from the pen were not different (P>0.67). Amount of N lost to volatilization and runoff (N not accounted for in manure of calculated as retained) was similar ($P \ge 0.60$) on both a kg per heifer basis and when expressed as a percentage of N intake. On a kg per heifer basis, losses were 22.4 kg and 21.1 kg for LOW and HIGH, respectively. Amount of N lost to volatilization and runoff expressed as a percentage of N excreted was 51.35% and 50.16% for LOW and HIGH starch:NDF barley, respectively.

Nitrogen retention by cattle was greater (P<0.01) for 25RUM compared to 48RUM due to ADG. However, DM and N removal from the pen in manure were not affected (P \geq 0.19) by monensin level. Amount of N lost was similar (P \geq 0.43) on both a kg per heifer basis and when expressed as a percentage of N intake. Volatilization losses were calculated by difference between the amount of nutrients excreted minus the amount removed from the pens, in the soil, and in the runoff.

When P balance data were analyzed, two barley x monensin interactions (P=0.04) were observed, for P intake and excretion. Phosphorus intake per heifer was greatest (P<0.01) for LOW/48RUM at 11.1 kg, 10.9 kg for both LOW/25RUM and HIGH/48 RUM, and 10.4 kg for HIGH/25RUM. Similar to differences in N intake, these differences are likely due to differences in DM intake. Retention of P per heifer was 0.1 kg greater (P<0.01) for LOW compared to HIGH. Excretion of P per heifer was greatest (P<0.01) for LOW/48RUM at 9.7kg, 9.5kg for HIGH/48RUM, 9.3 kg for LOW/25RUM, and 9.1 kg for HIGH/25RUM. Phosphorus removal from the pen was not different $(P \ge 0.97)$ among the two barley treatments. Phosphorus losses were similar $(P \ge 0.83)$ on both a kg per heifer basis and when expressed as a percentage of P intake. On a kg per heifer basis, losses were actually gains at -0.8 kg and -1.0 kg for LOW and HIGH, respectively. Expressed as a percentage of P intake, these losses were -8.43% and -11.02%, and were therefore actually gains. Phosphorus losses in the study conducted prior to the present study in the same pens were high (51.59%, on average, unpublished data). Presumably, some of the P from the previous trial was recovered when the pens were cleaned at the end of the present study.

Phosphorous retention per heifer was 0.1 kg greater (P=0.04) for 25RUM compared to 48RUM. Dry Matter and P removal from the pen were not affected (P≥0.19) by monensin level. Phosphorus losses were similar (P≥0.47) on both a kg per heifer basis and when expressed as a percentage of P intake. On a kg per heifer basis, losses were -1.4 kg and -0.4 kg for LOW and HIGH, respectively. Expressed as a percentage of P intake, these losses were -14.51% and-4.94%. Thus, P was actually gained in this experiment.

Manure excretions of N and P increased in response to increased nutrient intake.

Van Horn (1996) noted that diets that support increased efficiency of nutrient retention and production result in decreased amounts of excreted nutrients. In the present study, feed efficiency and nutrient retention were not affected by experimental group. Van Horn (1996) reported that performance enhancing feed additives have positive environmental impacts because they reduce manure production per unit of animal product production. However, in the present study, increasing the concentration of the feed additive monensin did not provide a benefit in terms of animal performance or nutrient losses.

In dry conditions, P may not be removed during pen cleaning because the soil is not as thoroughly mixed with the manure compared to wet conditions (Luebbe et al., 2012). Thus, the amount of P that is unaccounted for in mass balance studies is often greater during the summer (47.0%) compared to winter (5.8%) (Erickson and Klopfenstein, 2002). However, other authors have reported that a greater amount of P was unaccounted for in the winter (13.1%) compared to the summer (9.8%) (Kissinger et al., 2006b). In the present study, when the pens were cleaned in July and August, conditions were dry but the preceding months had been wet, perhaps allowing for sufficient mixing that contributed to the recovery of phosphorus.

Conclusions

Low starch:NDF barley based diets when segregated by NIRS technology appear to be better than high starch:NDF barley diets for dry matter intake ADG, final BW, and carcass weight. Feeding LOW starch:NDF barley decreased the percentage of YG 2

carcasses, increased the percentage of YG 3 carcasses, and tended to increase the percentage of YG 4 carcasses. The number of animals treated for respiratory disease was not affected by barley starch:NDF, but feeding low starch:NDF barley increased the number of miscellaneous mortalities. Feeding LOW barley increased N and P intake, excretion, and retention. These results would indicate that the low starch:NDF barley may be premium to that of the high starch:NDF barley.

Feeding 25 mg/kg improved DMI, ADG, final BW, and carcass weight compared to 48 mg/kg. Monensin concentration had minimal effects on carcass quality, number of treatments for respiratory disease, or overall mortality. Feeding 25 mg/kg decreased N and P intake and excretion and increased N and P retention. In addition, the differences between high quality barley and low quality barley appear to be subtle so further understanding of the important characteristics needed to segregate and properly price the barley is needed.

References

- AOAC. 2005. Official Methods of Analysis.18th Edition, Revision 4. AOAC International, Gaithersburg, MD.
- Boling, J. A., Bradley, N. W., and L. D. Campbell. 1977. Monensin levels for growing and finishing steers. J. Anim. Sci. 44:867-871.
- Burrin, D. G., and R. A. Britton. 1986. Response to monensin in cattle during sub acute acidosis. J. Anim. Sci. 63:888–893.
- Burrin, D. G., R. A. Stock, and R. A. Britton. 1988. Monensin level during grain adaptation and finishing performance in cattle. J. Anim. Sci. 66:513–521.
- Edney, M.J., Morgan, J.E., Williams, P.C., and L.D. Campbell. 1994. Analysis of feed barley by near infrared reflectance technology. J. Near Infrared Spectrosc. 2:33-41.
- Erickson, G.E., Milton, C.T., Fanning, K.C., Cooper, R.J., Swingle, R.S., Parrott, J.C., Vogel, G., and T.J. Klopfenstein. 2003. Interaction between bunk management and monensin concentration on finishing performance, feeding behavior, and ruminal metabolism during an acidosis challenge with feedlot cattle. J. Anim. Sci. 81:2869-2879.
- Edney, M.J., Morgan, J.E., Williams, P.C., and L.D. Campbell. 1994. Analysis of feed barley by near infrared reflectance technology. J. Near Infrared Spectrosc. 2:33-41.
- Fulton, W. R., T. J. Klopfenstein and R. A. Britton. 1979a. Adaptation to high concentrate diets by beef cattle. 1. Adaptation to corn and wheat diets. J. Anim. Sci. 49:775-784.
- Fulton, W. R., T. J. Klopfenstein and R. A. Britton. 1979b. Adaptation to high concentrate diets by beef cattle. 2. Effect of ruminal pH alteration on lumen fermentation and voluntary intake of wheat diets. J. Anim. Sci. 49:785-789.
- Galyean, M. L., Malcolm, K. J. and Duff, G. C. 1992. Performance of feedlot steers fed diets containing laidlomycin propionate or monensin plus tylosin, and effects of laidlomycin propionate concentration on intake patterns and ruminal fermentation in beef steers during adaptation to a high concentrate diet. J. Anim. Sci. 70: 2950-2958.
- Gibb, D.J., Streeter, M., Schwartzkopf-Genswein, K.S., and T.A. McAllister. Performance and bunk attendance of cattle fed steamrolled or ground corn supplemented with laidlomycin and chlortetracycline or monensin and tylosin. Can. J. Anim. Sci. 88:499-506.
- Goering, H.K. and P.J. Van Soest. 1970. Forage Fiber Analyses (apparatus, reagents, procedures, and some applications). ARS/USDA Handbook No. 379, Superintendent of Documents, US Government Printing Office, Washington, D.C. 20402. p15.

Goodrich, R. D., Garrett, J. E., Gast, D. R., Kirick, M. A., Larson, D. A., and J. C. Meiske. 1984. Influence of monensin on the performance of cattle. J. Anim. Sci. 58:1484–1498.

Helrich, K., and Padmore, J.M. 1990. Association of Official Analytical Chemists. Official Methods of Analysis (15th Ed.) Vol. 1. Arlington, VA.

Kirk, D. J., L. W. Greene, G. T. Schelling, and F. M. Byers. 1985. Effects of monensin on Mg, Ca, P and Zn metabolism and tissue concentrations in lambs. J. Anim. Sci. 60:1485-1490.

Nagaraja, T. G., Avery, T. B., Bartley, E. E., Galitzer, S. J., and A. D. Dayton. 1981. Prevention of lactic acidosis in cattle by lasalocid or monensin. J. Anim. Sci. 53:206–216.

Nagaraja, T. G., Avery, T. B., Bartley, E. E., Roof, S. K., and A. D. Dayton. 1982. Effect of lasalocid, monensin or thiopeptin on lactic acidosis in cattle. J. Anim. Sci. 54:649-658.

National Research Council, Nutrient Requirements for Beef Cattle, 7th Revised Edition, National Academy Press, Washington, DC.

Ovenell-Roy, K.H., Nelson, M.L., Froseth, J.A., Parish, S.M., and E.L. Martin. 1998. Variation in chemical composition and nutritional quality among barley cultivars for ruminants. 1. Steer finishing performance, diet digestibilities and carcass characteristics. Can. J. Anim. Sci. 78:369-375.

Owens, F.P., Secrist, D.S., Hill, W.J., and D.R. Gill. 1998. Acidosis in cattle: a review. J. Anim. Sci. 76:275-286.

Raun, A.P., Cooley, C.O., Potter, E.L., Rathmacher, R.P., and L.F. Richardson. 1976. Effect of monensin on feed efficiency of feedlot cattle. J. Anim. Sci. 43:670-677.

Reynolds, W. K., C. W. Hunt, J. W. Eckert, and M. H. Hall. 1992. Evaluation of the feeding value of barley as affected by variety and location using near infrared reflectance spectroscopy. Proc. West. Sec. Amer. Soc. Anim. Sci. 43:498-501.

Richardson, L. F., A. P. Raun, E. L. Potter, C. O. Cooley, and R. P. Rathmacher. 1976. Effect of monensin on rumen fermentation in vitro and in vivo. J. Anim. Sci. 43:657–664.

Smith, R.A. 1998. Impact of disease on feedlot performance: a review. J. Anim. Sci. 76:272-274.

Spears, J. W. 1990. Ionophores and nutrient digestion and absorption in ruminants. J. Nutr. 120:632-638.

Spires, H. R., Olmsted, A., Berger, L. L., Fontenot, J. P., Gill, D. R., Riley, J. G., Wray, M. I. and Zinn, R. A. 1990. Efficacy of laidlomycin propionate for increasing rate and efficiency of gain by feedlot cattle. J. Anim. Sci. 68: 3382-3391.

- Starnes, S. R., Spears, J.W., Froetschel. M.A., and W. J. Croom, Jr. 1984. Influence of monensin and lasalocid on mineral metabolism and ruminal urease activity in steers. J. Nutr. 114:518-525.
- Stock, R. A., S. B. Laudert, W. W. Stroup, E. M. Larson, J. C. Parrott, and R. A. Britton. 1995. Effects of monensin and monensin and tylosin combinations on feed intake variation of feedlot steers. J. Anim. Sci. 73:39–44.
- Stock, R.A., Sindt, M.H., Parrot, J.C., and F.K. Goedeken. 1990. Effects of grain type, roughage level and monensin level on finishing cattle performance. J. Anim. Sci. 68:3441-3455.
- Wolf, A., Watson M., and N. Wol- 2003. Digestion and dissolution methods for P, K, Ca, Mg and trace elements. Recommended methods of manure analysis. ed J. Peters, pp30, 32-35. University of Wisconsin Extension Publication. A3769.

Table 1. Definitions and calculations for cattle production lot variables from a study evaluating the effects of feeding high and low energy barley on feedlot cattle performance in western Canada

Animal Health Rates		
Initial UF Treatment	=	# of animals initially treated for UF divided by the # of animals
Initial NF Treatment	=	# of animals initially treated for NF divided by the # of animals
Overall Chronicity	=	# of animals with chronic disease divided by the # of animals
Overall Wastage	=	# of animals with chronic disease that didn't die divided by the # of
· ·		animals
Overall Mortality	=	# of mortalities (all causes) divided by the # of animals
BRD Mortality	=	# of mortalities due to BRD divided by the # of animals
HS Mortality	=	# of mortalities due to histophilosis divided by the # of animals
Lameness Mortality	=	# of mortalities due to lameness divided by the # of animals
Metabolic Mortality	=	# of mortalities due to metabolic disease divided by the # of animals
Other Mortality	=	# of mortalities (causes other than BRD, HS, lameness, or metabolic
		disease) divided by the # of animals
Production Variables		
Slaughter Weight	=	the total net live weight by multi-pen lots prior to slaughter divided by
		the # of animals sold and represents the average net live weight of
		animals sold for slaughter
Weight Gain	=	average slaughter weight minus the average initial weight and represents
		the average weight gain of animals sold for slaughter
Carcass Weight	=	total carcass weight at slaughter divided by the # of animals sold and
		represents the average carcass weight of animals sold for slaughter
Dressing Percentage	=	total carcass weight at slaughter divided by the total weight at slaughter
		expressed as a percentage
Days on feed	=	average slaughter date minus the average allocation date and represents
		the average # of days on feed of animals sold for slaughter
DMI	=	total quantity of feed consumed (100% dry matter basis) divided by the
		# of cattle days and represents the pounds of feed consumed per animal
		per day
Feedlot Performance V		
ADG ¹ –LWB ²	=	(total net slaughter weight plus total weight of animals shipped for
		salvage slaughter plus total weight of animals that died minus total
and gan?		initial weight) divided by the # of animals days
ADG^1 – CAB^2	=	(total carcass weight divided by a fixed dressing percentage (60.0%)
		plus total weight of animals shipped for salvage slaughter plus total
		weight of animals that died minus total initial weight) divided by the #
CEL LWD2		of animal days
$G:F^1 - LWB^2$	=	DMI divided by ADG – LWB
$G:F^1 - CAB^2$	=	DMI divided by ADG – CAB

^{3.} UF is undifferentiated fever, NF is no fever, BRD is bovine respiratory disease, HS is lesions consistent *Histophilus somni* infection, BVD is bovine viral diarrhea, DMI is daily dry matter intake, ADG is average daily gain, G:F is gain to dry matter intake ratio.

^{4.} LWB is live weight basis and CAB is carcass-adjusted basis.

Table 2. Diet composition and chemical analyses of the total mixed rations fed in a study evaluating the effects of feeding high and low starch:NDF barley and 25 or 48 mg/kg monensin on feedlot cattle performance in western Canada

	LC	W^1	HIO	GH ¹
Item ³	25^{2}	48^{2}	25^{2}	48^{2}
Ingredient				
LOW starch:NDF barley	78.08	78.08	-	-
HIGH starch:NDF barley	-	-	78.08	78.08
DDGS	20.00	20.00	20.00	20.00
Supplement ⁴	1.92	1.92	1.92	1.92
Nutrient Composition, ⁵				
Number of Samples ⁶	17	17	17	16
Dry Matter	81.60	81.28	81.92	82.04
CP	17.38	18.28	17.04	18.09
Fat	5.65	6.37	5.49	6.09
NDF	20.16	20.89	19.73	20.72
Starch	34.86	32.17	35.71	32.93
Phosphorus	0.62	0.65	0.61	0.64
Potassium	0.76	0.79	0.74	0.76

HIGH barley is barley that was segregated based on a high starch:NDF ratio (>3.25). LOW barley is barley that was segregated based on a low starch:NDF ratio (<3.25). Mean and SD for starch:NDF for HIGH and LOW was 3.15 ± 0.16 and 2.80 ± 0.19 , respectively.

². 25 is 25mg/kg monensin included in the diet, 48 is 48mg/kg monensin included in the diet.

^{3.} All numbers are expressed as percentages on a 100% DM basis.

Supplement was manufactured at Landmark Feeds (Strathmore, AB) and included 27.6 mg/kg DM monensin (Rumensin, Elanco Animal Health, Indianapolis, Indiana), 12.1 mg/kg DM tylosin (Tylan, Elanco Animal Health), and 0.5 mg/heifer daily melengestrol acetate (MGA, Pfizer Animal Health, Kirkland, QC).

^{5.} Analysis performed by DairyOne, Ithaca, NY.

⁶ One sample from HIGH/48 was removed from the analysis due to a high fat content.

Table 3. Growth performance and carcass characteristic data summary from a study evaluating the effects of feeding high and low starch:NDF barley and 25 or 48 mg/kg monensin on feedlot cattle performance in western Canada

	BAR	LEY ¹	RUME	ENSIN ²		P-Value		
Item	HIGH	LOW	25	48	SEM	BARLEY	RUM	INT
Carcass Adjusted Perfe	ormance³							
Final BW, kg	521.5	528.7	529.2	521.1	1.95	< 0.01	< 0.01	0.28
Weight Gain, kg	248.7	255.4	255.8	248.4	1.63	< 0.01	< 0.01	0.10
ADG, kg	1.09	1.11	1.11	1.08	0.01	< 0.01	< 0.01	0.46
G:F	0.148	0.149	0.149	0.148	0.00	0.24	0.30	0.72
Live Performance ⁴								
Initial BW, kg	268.1	269.0	268.6	268.6	2.14	0.06	0.93	0.80
Final BW, kg	513.8	519.5	519.3	514.0	1.68	< 0.01	< 0.01	0.14
Weight Gain, kg	245.7	250.5	250.8	245.4	1.50	< 0.01	< 0.01	0.07
ADG, kg	1.10	1.07	1.07	1.05	0.01	< 0.01	< 0.01	0.27
G:F	0.143	0.143	0.143	0.144	0.00	0.72	0.34	0.91
DMI, kg/hd/d	7.3	7.5	7.5	7.3	0.04	< 0.01	< 0.01	0.20
Carcass								
characteristics								
HCW, kg	314.0	318.0	318.3	313.7	1.13	< 0.01	< 0.01	0.15
12 th Rib Fat, cm	1.04	1.10	1.10	1.04	0.02	< 0.01	< 0.01	0.53
LM Area, cm ²	79.3	79.2	79.1	12.3	0.76	0.90	0.35	0.82
Marbling Score ⁵	446	457	454	450	3.2	< 0.01	0.21	0.23
Dressing %	61.11	61.21	61.30	61.03	0.07	0.18	< 0.01	0.46

HIGH barley is barley that was segregated based on a high starch:NDF ratio (>3.25). LOW barley is barley that was segregated based on a low starch:NDF ratio (<3.25). Mean and SD for starch:NDF for HIGH and LOW was 3.15 ± 0.16 and 2.80 ± 0.19, respectively. In each treatment, there were 8 replicates (16 pens). 4,811 animals were allocated to HIGH and 4,806 to LOW

²⁵ is 25mg/kg monensin included in the diet, 48 is 48mg/kg monensin included in the diet. In each treatment, there were 8 replicates (16 pens). 4,807 animals were allocated to 25 and, 4,810 to 48.

Carcass Weight Basis values were calculated using carcass weights converted to live weights using a fixed dressing % of 60.0%.

^{4.} Live Weight Basis values were calculated using shrunk live weights obtained prior to slaughter.

^{5.} Marbling Score 600=Modest, 500=Small, 400=Slight

Table 4. Yield and quality grade data summary from a study evaluating the effects of feeding high and low starch:NDF barley and 25 or 48 mg/kg monensin on feedlot cattle performance in western Canada

	BAI	RLEY ¹	RUM	ENSIN ²			P-Value	ie	
Item ³	HIGH	LOW	25	48	SEM	BARLEY	RUM	INT	
USDA Yield Gre	ade								
1	14.61	12.95	12.15	15.41	1.40	0.14	0.01	0.78	
2	44.19	40.34	41.43	43.09	1.34	>0.01	0.23	0.48	
3	32.82	36.88	36.17	33.54	2.05	>0.01	0.03	0.89	
4	5.81	7.35	7.57	5.59	0.69	0.07	0.02	0.18	
5	2.57	2.48	2.68	2.36	1.86	0.75	0.26	0.39	
USDA Quality (Grade								
Prime	0.05	0.04	0.02	0.07	0.03	0.92	0.27	0.27	
Choice	23.48	27.60	26.02	25.06	1.21	>0.01	0.39	0.44	
Select	43.42	44.51	44.93	43.00	0.88	0.36	0.11	0.87	
Standard	33.05	27.85	29.03	31.87	1.56	>0.01	0.08	0.66	

High barley is barley that was segregated based on a high starch:NDF ratio (>3.25). Low barley is barley that was segregated based on a low starch:NDF ratio (<3.25). Mean and SD for starch:NDF for HIGH and LOW was 3.15 ± 0.16 and 2.80 ± 0.19 , respectively.

² 25 is 25mg/kg monensin included in the diet, 48 is 48mg/kg monensin included in the diet.

^{3.} All numbers are expressed as percentages.

Table 5. Morbidity and mortality data summary for a study evaluating the effects of feeding high and low starch:NDF barley and 25 or 48 mg/kg monensin on feedlot cattle performance in western Canada

	$BARLEY^1$		RUME	RUMENSIN ²			P-Value	
Item ³	HIGH	LOW	25	48	SEM	BARLEY	RUM	INT
Morbidity ⁴								
First UF Treatment	7.76	8.95	8.60	8.11	0.15	0.28	0.56	0.39
First NF Treatment	2.39	3.42	2.97	2.84	0.18	0.20	0.74	0.28
First Bloat Treatment	0.00	0.02	0.00	0.02	N/A	N/A	N/A	N/A
Chronicity	1.53	1.31	1.33	1.52	0.12	0.19	0.26	0.15
Wastage	1.16	0.96	0.87	1.25	0.14	0.27	0.02	0.07
Mortality ⁴								
Overall Mortality	2.89	3.00	3.27	2.62	0.11	0.79	0.13	0.13
BRD Mortality	0.75	0.62	0.61	0.77	0.20	0.47	0.43	0.93
Lameness Mortality	0.12	0.06	0.13	0.06	0.65	0.18	0.51	0.15
Metabolic Mortality	0.62	0.67	0.79	0.50	0.19	0.84	0.11	0.15
Miscellaneous Mortality	0.50	0.94	0.96	0.48	0.15	0.03	0.08	0.99

High barley is barley that was segregated based on a high starch:NDF ratio (>3.25). Low barley is barley that was segregated based on a low starch:NDF ratio (<3.25). Mean and SD for starch:NDF for HIGH and LOW was 3.15 ± 0.16 and 2.80 ± 0.19 , respectively.

² 25 is 25mg/kg monensin included in the diet, 48 is 48mg/kg monensin included in the diet.

^{3.} All numbers are expressed as percentages.

^{4.} UF is undifferentiated fever, NF is no fever, and BRD is bovine respiratory disease.

Table 6. Chemical analyses of manure samples from a study evaluating the effects of feeding high and low starch:NDF barley and 25 or 48 mg/kg monensin on feedlot cattle performance in western Canada

	BARLEY ¹		RUMENSIN ²			P-value		
Nutrient ^{3,4}	HIGH	LOW	25	28	SEM	Barley	RUM	Interaction
Number of Samples ⁵	32	32	32	32	-	-	-	-
DM Removed, kg/heifer	3153.8	2775.3	3214.9	2928.0	271.22	0.67	0.19	0.85
Dry Matter	51.68	48.13	46.67	53.14	1.88	0.19	0.02	0.20
Organic Matter	19.29	17.96	18.21	19.04	0.59	0.12	0.33	0.60
Nitrogen	0.59	0.54	0.54	0.59	0.02	0.13	0.12	0.34
Phosphorus	0.29	0.26	0.27	0.28	0.01	0.07	0.48	0.28
Calcium	2.20	1.96	1.95	2.22	0.10	0.11	0.07	0.23
Potassium	0.46	0.43	0.43	0.45	0.01	0.20	0.22	0.61
Starch	0.32	0.21	0.26	0.28	0.05	0.09	0.75	0.87

High barley is barley that was segregated based on a high starch:NDF ratio (>3.25). Low barley is barley that was segregated based on a low starch:NDF ratio (<3.25). Mean and SD for starch:NDF for HIGH and LOW was 3.15 ± 0.16 and 2.80 ± 0.19 , respectively.

² 25 is 25mg/kg monensin included in the diet, 48 is 48mg/kg monensin included in the diet.

^{3.} All numbers are expressed as percentages on a 100% dry matter basis.

^{4.} Chemical analyses were performed by Dairy One, Ithaca, NY.

Two composites were formed using 20 subsamples for each composite. Subsamples were collected as manure was scraped into a pile in the middle of the pen. Both composites were submitted for analysis and the average of the two composites was used in the analysis.

Table 7. Nitrogen mass balance summary from a study evaluating the effects of feeding high and low starch:NDF barley and 25 or 48 mg/kg monensin on feedlot cattle performance in western Canada

	HIGH ¹		LOW ¹			P-Value			
Item ³	25	48	25	48	SEM	BARLEY	RUM	INT	
Average days	228	230	230	229	1.6	0.63	0.84	0.13	
Intake	47.0	49.1	49.3	50.0	0.45	< 0.01	< 0.01	< 0.01	
Retention ⁴	6.0	5.8	6.1	5.9	0.04	< 0.01	< 0.01	0.22	
Excreted ⁵	41.0	43.3	43.2	44.1	0.45	< 0.01	< 0.01	< 0.01	
Removed ⁶	21.0	21.2	21.3	20.9	1.79	0.95	0.86	0.49	
Loss	20.6	21.6	20.9	24.0	1.79	0.60	0.43	0.67	
Loss, %	50.64	49.69	48.24	54.47	5.90	0.84	0.66	0.55	

High barley is barley that was segregated based on a high starch:NDF ratio (>3.25). Low barley is barley that was segregated based on a low starch:NDF ratio (<3.25). Mean and SD for starch:NDF for HIGH and LOW was 3.15 ± 0.16 and 2.80 ± 0.19 , respectively.

² 25 is 25mg/kg monensin included in the diet, 48 is 48mg/kg monensin included in the diet.

^{3.} All numbers expressed on a kg/heifer basis.

^{4.} Retention is retention in the animal calculated from NRC equations (NRC, 1996)

^{5.} Excreted is calculated as the difference between intake and retention

^{6.} Removed is the waste material removed from feedlot surface when pens were cleaned after all animals had been shipped for slaughter

^{7.} Runoff is included in the loss and is less than 5% of the total N loss.

Table 8. Phosphorus mass balance summary from a study evaluating the effects of feeding high and low starch:NDF barley and 25 or 48 mg/kg monensin on feedlot cattle performance in western Canada

Item ³	HIGH ¹		LOV	LOW ¹		P-Value			
	25	48	25	48	SEM	BARLEY	RUM	INT	
Average days	228	230	230	229	1.6	0.63	0.84	0.13	
Intake	10.4	10.9	10.9	11.1	0.10	< 0.01	< 0.01	0.04	
Retention ⁴	1.5	1.4	1.5	1.4	0.01	< 0.01	< 0.01	0.20	
Excreted ⁵	9.1	9.5	9.3	9.7	0.10	< 0.01	< 0.01	0.04	
Removed ⁶	10.2	10.5	11.1	9.6	1.26	0.97	0.65	0.50	
Loss	-1.1	-1.0	-1.6	0.07	1.25	0.83	0.47	0.54	
Loss, %	-11.48	-10.56	-17.54	0.68	13.27	0.85	0.48	0.52	

High barley is barley that was segregated based on a high starch:NDF ratio (>3.25). Low barley is barley that was segregated based on a low starch:NDF ratio (<3.25). Mean and SD for starch:NDF for HIGH and LOW was 3.15 ± 0.16 and 2.80 ± 0.19 , respectively.

² 25 is 25mg/kg monensin included in the diet, 48 is 48mg/kg monensin included in the diet.

^{3.} All numbers expressed on a kg/heifer basis.

^{4.} Retention is retention in the animal calculated from NRC equations (NRC, 1996)

^{5.} Excreted is calculated as the difference between intake and retention

⁶ Removed is the waste material removed from feedlot surface when pens were cleaned after all animals had been shipped for slaughter

^{7.} Runoff is included in the loss and is less than 5% of the total P loss.

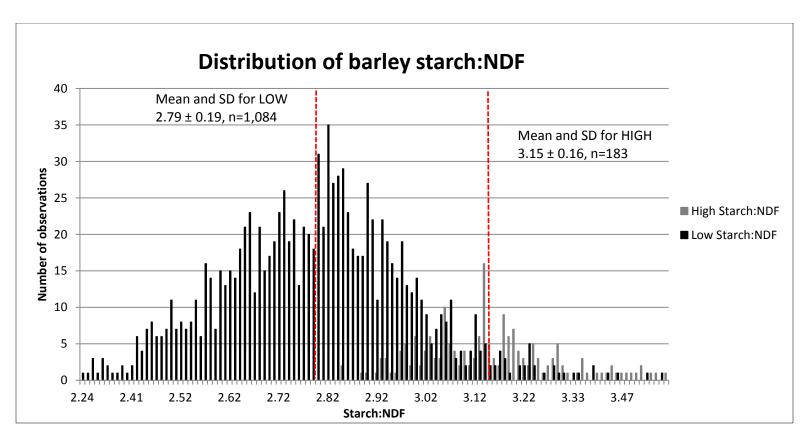


Figure 1. Distribution of starch:NDF of barley measured by near infrared spectroscopy (NIRS) in a study evaluating the effects of feeding high and low starch:NDF barley and 25 or 48 mg/kg monensin on feedlot cattle performance in western Canada

High barley is barley that was segregated based on a high starch: NDF ratio (>3.25). Low barley is barley that was segregated based on a low starch: NDF ratio (<3.25). Adjustments had to the cut off value had to be made during the study based on the starch: NDF ratio of incoming barley.