EVALUATION OF DRIED DISTILLERS GRAINS COMPARED TO BARLEY IN EXTENSIVE GRAZING SCENARIOS FOR STOCKER CATTLE

A Thesis Submitted to the

College of Graduate Studies and Research

In Partial Fulfillment of the Requirements

For the Degree of Master of Science

In the Department of Animal and Poultry Science

University of Saskatchewan

Saskatoon, SK

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ABSTRACT

Three experiments were conducted to determine the effects of dry distillers grains (DDGS) on calf performance, forage utilization, and production costs. In addition, a digestibility trial was conducted using ram lambs to determine the effects of supplement on nutrient digestibility and intake. In 3 field grazing trials, 54 crossbred yearling beef calves (mean BW±SD; 258.1±7.3kg) were stratified by body weight (BW) and randomly allocated to 1 of 3 replicated (n=2) supplement strategies. Calves were managed on fall stockpiled crested wheatgrass pasture (OMD=48.1%, CP=6.2% (DM)) in experiment one (EXP 1) and summer pasture in experiment three (EXP 3) (OMD=57.0%, CP=14.4% (DM)). For experiment two (EXP 2) the same calves form EXP 1 were managed on a bale grazing (OMD=45.3%, CP=7.1% (DM)) program on dormant pasture. EXP 1 supplement treatments were (1) 70% barley + 30% canola meal (CONT); (2) 70% barley + 30% DDGS (70:30); and (3) 100% DDGS. EXP 2 and EXP 3 supplementation treatments were (1) 100% barley (CONT); (2) 50% barley + 50% DDGS (50:50); and (3) 100% DDGS. Forage utilization was measured for all grazing trials using the herbage weight disappearance method. Calf BW was measured at start and end of trial and every 14 d throughout. There was no effect ($P>0.05$) of supplementation on forage utilization in EXP 1 or EXP 2. Pasture utilization was greater ($P=0.04$) in EXP 3 for CONT and 50:50 supplement strategies compared to DDGS supplemented calves. There was no effect ($P>0.05$) of supplement strategy on calf performance in terms of body weight change in all 3 field grazing studies. Costs per calf per d in EXP 1 were $0.80, $0.79 and $0.77 for DDGS, 70:30 and CONT, respectively. Costs per calf per d in EXP 2 were $1.53, $ 1.51, and $1.53 for DDGS, 50:50 and CONT, respectively. Costs per calf per d for EXP 3 were $1.84, $1.78, and $1.71 for DDGS, 50:50 and CONT, respectively.

In experiment four (EXP 4), 24 Suffolk ram lambs (mean BW±SD; 43.5±5 (kg)) were fed a grass legume hay (OMD=54.17%, CP=7.17% (DM)) and supplemented with either (1) 100% DDGS; (2) 50% barley and 50% DDGS; (3) 100% barley (CONT). Forage intake and apparent total tract digestibility were measured. Forage intake was not (P>0.05) affected by supplementation strategy. Digestibility of CP (P=0.01) and ADF (p=0.02) were significantly higher for DDGS supplemented calves, compared barley supplemented calves. However, organic matter digestibility (OMD) and dry matter digestibility (DMD) were not different between supplement strategies.

The results of all 4 experiments suggest that DDGS can be used as a suitable supplement for growing beef calves or sheep in extensive pasture scenarios, while consuming grass-legume hay. DDGS had similar effects on calf performance, forage utilization, and digestibility. Because of this, the inclusion of DDGS as a supplement for ruminants will depend on the initial price of the supplement.

ACKNOWLEDGMENTS

The process of accomplishing a Master's project and writing a thesis requires one to work with, and rely on a team of people teaching and helping along the way. I wouldn't have traded my team for the world! First I would like to thank Dr. Bart Lardner for his patience, expertise, guidance, and support. My committee members Dr. Dave Christensen and Dr. John McKinnon have showed me patience, support and an open door. I thank them for always making time to go above and beyond to help me. I would also like to thank my chair Dr. Fiona Buchanan for her advice and help extending my program. I cannot express enough words to thank the people at Western Beef Development Center (George Widdefield, Leah Pearce, Johnathan pearce, Ashley Guenther, and summer students) for all of their help and friendship during my trials. I was so thankful to have the opportunity to do my lab work at SPARC research center in Swift Current. Dr. Iwassa has a wonderful team there that was a blast to work with (Ed Dale, Lindsay, and Curtis). The friendship and help of my fellow students and technicians in the department was so valuable you all know who you are! Most of all, I would like to thank my family and extended family. A special thanks to my grandparents, who helped with some of the financial burdens of school. Grandpa did not want the cost of school to be an excuse for his grandchildren to not have access to secondary education. I know that I would have not gone this far in school without that help.

Finally, I would like to thank my husband PJ who has been supportive of all my endeavors inside and outside of school and my parents, Dave and Trish, for their continued support and encouragement throughout my education. This thesis is dedicated to my little girl Tegan and Baby on the way who can do and be anything they want to when they put their mind to it.

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LIST OF ABBREVIATIONS

ADG	Average daily gain
ADF	Acid detergent fiber
BW	Body weight
°C	Degree Celsius
Ca	Calcium
CO_2	Carbon dioxide
CP	Crude protein
d	Day
DDG	Dried distillers grains
DDGS	Dried distillers grains with solubles
DE	Digestible energy
DM	Dry matter
DMD	Dry matter digestibility
DMI	Dry matter intake
EE	Ether extract
hd	Head
Kg	Kilogram
Mcal	Mega calorie
N	Nitrogen
NDF	Neutral detergent fiber
NE_g	Net energy of gain
NE_m	Net energy of maintenance
NPN	Non protein nitrogen
NRC	National research council

OMD	Organic matter digestibility
P	Phosphorus
pH	Potential hydrogen
S	Sulphur
SAS	Statistical analysis system
SD	Standard deviation
SEM	Standard error of the mean
T_p	Previous temperature
TDN	Total Digestible nutrients
WDG	Wet distillers grains
WDGS	Wet distillers grains plus solubles
$	Dollars
%	Percent

1.0 Introduction

The stocker or backgrounding industry in North America is made up of many different management and nutritional programs. This diversity can be attributed to producers attempting to minimize their costs of production in this sector of the beef industry. The main focus of feeding cattle at the backgrounding stage is to focus on skeletal and muscle growth of the animal while minimizing fat deposition (Block et al. 2001). Typical backgrounding diets in Saskatchewan are comprised of 60-70% forages with the rest of the diet composed of a concentrate source such as barley or other grain types (Klinger 2005; Beauchemin and McGinn 2005).

The current expansion of the ethanol Industry in Canada has resulted in the increased availability of co-products such as dried distillers grain plus solubles (DDGS). DDGS is the end product once a commodity (wheat or corn) has gone through the fermentation process of ethanol production (Belyea et al. 2004). The fermentation process consumes almost all the starch present in the initial grain, resulting in a threefold increase in the concentration of the remaining nutrients in DDGS (Klopfenstein et al. 2008). Co-product quality depends on many factors within the fermentation process, including pre-processing of the grain, how the DDGS was dried and quality of the grain used to produce the ethanol (Nuez-Ortin and Yu 2010a). Wheat is the most common grain used for ethanol production in Saskatchewan because of its availablility. Currently there is limited research available evaluating the use of wheat DDGS as a supplement in extensive backgrounding programs. However, in several ruminant drylot feeding studies, DDGS has been shown to be an excellent ingredient when included in rations at or above 20% of total diet

(DM basis) (Nichols et al. 1998; Liu et al. 2000; Schingoethe 2001; Beliveau and McKinnon 2008; Aldai et al. 2010; Li et al. 2011; Yang et al. 2012).

Co-products from the ethanol industry are known to have high protein content (Klopfenstein et al. 2008; Ham et al. 1994). This is of particular importance to the animal nutrition industry, as protein in ruminant rations is one of the more expensive ingredients that will influence diet cost. Protein supplementation is effective because it provides a nitrogen (N) source to facilitate a healthy rumen bacterial population to enhance forage digestibility in the diet (Van Soest 1994). With the expansion of the ethanol industry and previous research demonstrating how wheat DDGS is a suitable ingredient for dairy and feedlot rations, more research is needed to examine animal performance supplementing wheat DDGS in an extensive grazing program for stocker cattle.

The objectives of this literature review are to: 1. Provide an overview of the Canadian ethanol industry and co-product production; 2. Review the nutrient characteristics of wheat and wheat based DDGS; 3. Discuss the stocker backgrounding industry in Canada focusing on summer and winter programs; 4. Review supplementation of ruminant rations focusing on barley and wheat DDGS; 5. Evaluate methods of determining pasture productivity and forage quality.

2.0 Literature Review

2.1 The Canadian Ethanol Industry

Over the past decade the Canadian government has introduced policies, funding and programs focused on supporting renewable fuels. These initiatives have resulted in substantial monetary support aimed at expanding the Canadian ethanol industry. Government incentives into the renewable fuel industry can be attributed to the goals of decreasing greenhouse gas emissions, decreasing fuel price and securing fuel for Canada's future and stimulating the agricultural economy (Weseen and Hobbs 2010a).

In western Canada the most abundant and established renewable fuel is ethanol produced from wheat grain. This fuel from starch fermentation is referred to as first generation ethanol production (Weseen and Hobbs 2010a). Ethanol plants in western Canada produce ethanol from two main grain sources. The first is wheat which is the predominant grain available in western Canada suitable for ethanol production while other plants import corn and produce ethanol from corn or wheat-corn blends. The grain to ethanol conversion factor is estimated to be 365 L: tonne of wheat with the DDGS to tonne of wheat conversion at 290 kg: tonne (Racz 2007). In 2009, western Canada used 1.3 million metric tonnes of grains (wheat and corn) to produce over 500 million litres of ethanol (Canadian Renewable Fuels Association (CRFA) 2009; University of Saskatchewan 2009). This level of ethanol production creates roughly 460 thousand metric tonnes of DDGS (University of Saskatchewan 2009).

2.1.1 Co-product Production

The main steps of ethanol production are depicted in the Figure 1. The steps are similar for all dry grind ethanol plants. Kaiser (2005) and Stock et al. (2000) explain the fundamental steps of dry grind ethanol production that include grinding, cooking, liquefaction, scarification and fermentation. The first step described for ethanol production is preparing the grain. Grain preparation or milling is typically done by dry milling. This process increases the surface area of the grain increasing enzyme availability (Stock et al. 2000). After milling, the first addition to the grain is water and amylase. Together the water and grain create a slurry or mash that is cooked under pressure to decrease microbes and gelatinize the starch in what is called the liquefaction phase. At the end of the liquefaction phase the slurry is cooled and enzymes are added to convert liquefied starch into fermentable sugars (Stock et al. 2000; Bothast and Schlicher 2005). Fermentation is the next step. During fermentation yeast is added to the cooled slurry. Yeast converts all of the available starch into carbon dioxide (CO_2) and ethanol with distillers grains left as a co-product (Spiehs et al. 2002).

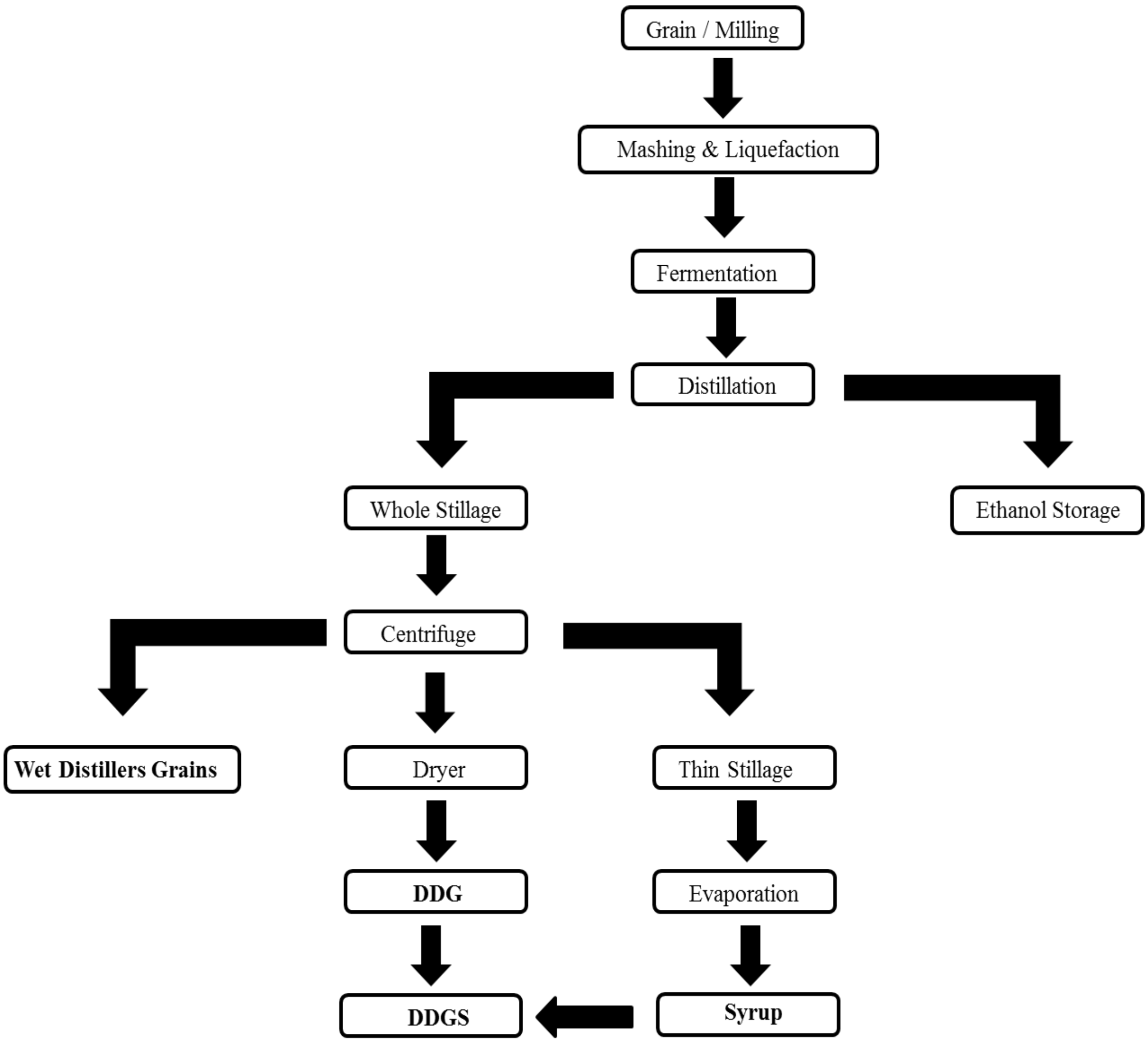

Fig. 1. Flow diagram of ethanol and co-product production and processing (Adapted from Shurson 2008).

Once the fermentation process is finished, distillation takes place to separate ethanol from the rest of the slurry which is now called whole stillage (Stock et al. 2000; Gibb et al. 2008). Whole stillage can be fractioned via centrifuge to make up thin stillage and wet distillers grains (Stock et al. 2000). Thin stillage can be fed directly to animals or can be dried down further to syrup which is often added to wet distillers grains. Wet distillers grains with the added syrup or solubles is called wet distillers grain with solubles and when dried down further to ease handling, transport and to decrease spoilage, is called dried distillers grain with solubles (DDGS) (Stock et al. 2000).

2.1.2 Types of Co-products

There are different types of co-products available from dry grind ethanol production. These co-products differ in how they were processed after ethanol production. The separation process of the various co-products is shown in Figure 2.1.

The whole stillage is typically fractionated into 2 products, wet distillers grains (WDG) and thin stillage. Wet distillers grains usually range between 30-35% dry matter (DM) and thin stillage ranges from 4-8% DM (Beliveau 2008; Ham et al. 1994; Ojowi et al. 1996). Poundmaker Agventures at Lanigan, Saskatchewan is a vertically integrated ethanol plant with a feedlot facility. At Poundmaker screening is all the processing necessary for the co-products as both fractions can be fed in diets directly to the animals in the feedlot without the risk of spoiling. When transportation of the co-product is necessary, the WDG is dried down and called dry distillers grains (DDG). The DM content of DDG is around 90% (Beliveau and McKinnon 2008; Fischer et al. 1999).

Thin stillage can also undergo variable drying to produce different co-products. If an evaporation process is used, thin stillage may be considered syrup or condensed distillers' solubles. Because of nutrients left behind, syrup is usually added back to the distillers grains and dried to make dried distillers grains with solubles (DDGS). In a study conducted by Fisher et al. (1999), wheat based thin stillage fed as a water source to feedlot cattle showed a trend ($P<0.10$) of increasing carcass fat and a significant ($P<0.05$) increase in DM digestibility and crude protein (CP) content. Similar digestibility results were discovered by Ojowi et al. (1996) who found that steers grazing crested wheatgrass pasture and received thin stillage as their water source, had a significant increase (P<0.05) in growth compared to animals grazing similar pasture consuming only water. Syrup can be added to WDG to produce wet distillers grains with solubles (WDGS). If the ethanol plant is producing DDG and the thin stillage is added back to the DDG and dried, this product is called DDGS. Dried distillers grains plus solubles is the main ethanol co-product available to both the monogastric and ruminant livestock industries.

2.2 Characteristics of Wheat DDGS

More recently DDGS has been evaluated in several studies focusing on its use in dairy, beef, poultry, pork and fish rations. Compared to wheat and barley grain, wheat based DDGS are noted for their exceptionally high protein content (Nuez-Ortin 2010a). This high CP content is a desired characteristic for animal diets, as protein is often one of the more costly additives in rations. One theory proposed was that DDGS could replace part of the forage within a ration due to the high fiber content of DDGS. This theory was dismissed due to the fact that there is little effective fiber contained within DDGS and that DDGS has not been shown to reduce the rumen pH of feedlot diets (Shingoethe et al. 2009; Walter 2010). Wheat DDGS has also been observed to have reasonable energy content. This can be attributed to a highly digestible fiber fraction and elevated fat (4.98%) present in the co-product (Nuez-Ortin 2010). Characteristics of wheat DDGS are largely influenced by the ethanol production process. The nutrient composition of DDGS proportionally reflects the nutrient composition of the grain sources used after starch removal (Lodge et al. 1997; Mustafa et al. 2000a; Shurson 2005). Barley has been traditionally used as a grain source in ruminant rations within western Canada. A recent study by Beleveau and McKinnon (2008), demonstrated that wheat based DDGS supplied both the energy and protein needed for finishing cattle and was an adequate replacement for barley in the finishing rations (Beliveau and Mckinnon 2008). Since then there have been numerous studies demonstrating the safe and efficient use of DDGS supplying protein and energy in ruminant diets

(Aldai et al. 2010; Beliveau and McKinnon 2008; Li et al. 2011;Schingoethe 2001; Liu et al. 2000; Nichols et al. 1998; Yang et al. 2012).

2.2.1 Crude Protein

The CP content of wheat DDGS can be variable. Nuez-Ortin (2010) compared several ethanol plants for nutrient composition of wheat DDGS and found that CP values ranged from 30.5 to 45.8% (DM basis). This is an extremely large range considering NRC (2000) recommends that CP content should be 8-12 percent for a backgrounding ration. The fluctuation of CP can be attributed to variation of the initial grain used and extent of processing, extent of yeast inclusion in the fermentation process, and extent and conditions of drying the DDGS (Nuez-Ortin 2010). Another consideration when formulating ruminant rations is the percentage of CP present that is rumen undegradable protein (RUP) but still degradable in the small intestine. This suggests that the CP can still be used for ruminant metabolism processes by avoiding assimilation into microbial protein and then digested which is a more energy consuming process. One of the main factors influencing variability of CP availability to the ruminant is the drying conditions of DDGS (Kleinschmit et al. 2007; Nuez-Ortin 2010). The variability of indigestible protein in DDGS is reported to be 0.7 to 7.6% of total CP (Nuez- Ortin 2010). Fluctuations in drying conditions are of particular concern because exact drying conditions differ both within and between ethanol plants. It has been found that drying DDGS with too much heat makes CP less available to the ruminant, both within the rumen environment and intestinally (Cozannet et al. 2010). Cozannet et al. (2010) found that wheat based DDGS can contain varying amounts of Maillard by-products. The Maillard reaction occurs when heat is present and facilitates residual sugars and amino acids to react and form an indigestible Maillard by-product (Van Soest 1994). The most susceptible amino acid that is involved in this reaction is lysine because of its free amino group which easily reacts to reducing sugars (Almeida et al. 2013). This decrease in CP availability may be attributed to temperatures reached during the liquefaction and drying stages of ethanol production (Arieli et al. 1989; McKinnon et al. 1995).

2.2.2 Energy

Research conducted comparing wheat and wheat-based DDGS to barley in backgrounding and finishing diets has shown that DDGS can adequately replace barley as an energy source for growing beef animals in intensive production scenarios (McKinnon and Walker 2008; Beliveau 2008; Walter 2010). A study by Van de Kerchhove et al. (2011) demonstrated that wheat-based DDGS was a comparable energy supplement to barley grain, when fed to cows in extensive stockpiled pasture systems. However, there is still limited information on wheat-based DDGS fed as an energy supplement to backgrounding calves in extensive pasture programs. The advantage of wheat based DDGS as an energy supplement is that the net energy of gain (NE_g) for wheat-based DDGS ranges from 1.26 to 1.41 Mcal kg^{-1} (Beliveau and McKinnon 2008; Gibb et al. 2008; Nuez Ortin and Yu 2009b), which is similar to 1.4 Mcal kg^{-1} for barley (NRC 2000). Part of the energy in DDGS is thought to be delivered to the animal in the form of fat. The fat content of wheat DDGS has been shown to be around 5% as determined by ether extract (Walter 2010) and remains considerably constant when comparing different ethanol plants and is more fully dependant on the fat composition of the initial grain used (Nuez Ortin 2010). Although fat delivers 2.25 times the energy of starch, the 5% fat content of wheat DDGS does not explain the full extent of the energy derived from wheat dried distillers grain plus solubles (Pritchard and Milton 2012; Jolly et al 2013). Therefore it has been hypothesized that there are other fiber based factors contributing to the energy value of wheat-based dried distillers grain plus solubles (Schingoethe 2006b; Nuez Ortin 2010). One factor that may attribute to this elevated energy content is that the neutral detergent fiber (NDF) content of the DDGS is highly digestible and had lower amounts of lignin present than parent grains (Schingoethe 2006b). Lignin is the non-digestible fiber fraction found in most feeds. The fact that the lignin fraction is substantially lower, indicates a better overall digestibility of the co-product (Nuez-Ortin 2010). The NDF content of wheat based DDGS ranges from 30 to 57% and has been found to be highly digestible (Nuez-Ortin 2010). It has been suggested that the elevated NDF digestibility may be due to the elevated CP content of the co-product which has been associated with increasing both the ruminal and total tract digestibility of NDF (Mustafa et al. 2000a).

Table 2.1. Nutrient composition of wheat and corn grain and distillers grains with solubles

Item	Corn		Wheat	
	Grain[z]	DDGS[x]	Grain[z]	DDGS[v]
DM (%)	90.0	88.9	90.2	93.8
Crude protein	9.8	30.2	14.2	39.3
Crude fat	4.1	10.9	2.3	5.0
Acid detergent fiber	3.3	16.2	4.2	11.0
Neutral detergent fiber	10.8	42.1	11.8	48.1
Calcium	0.03	0.06	0.05	0.18
Phosphorus	0.32	0.89	0.44	0.91

Adapted from Walter, 2010: Data sourced from: [z]NRC 2000; [x]Speihs et al. 2002; [v]Nuez-Ortin and Yu 2009

2.2.3 Minerals

NRC (2000) guidelines regarding proper mineral intake for ruminants must be considered when incorporating wheat DDGS into a beef ration. It is important to note that the phosphorus (P) level of wheat DDGS is elevated while the calcium (Ca) content tends to be lower in the ration with addition of DDGS. This is cause for concern especially for young beef animals in the skeletal development stage of growth as the recommended Ca:P ratio recommended is from 1:1 to 7:1 (NRC 2000). Therefore addition of a Ca supplement in the ration is required when feeding wheat DDGS. Sulphur (S) levels can also be an issue when feeding wheat DDGS, as S is added to the slurry in the ethanol production process to decrease potential hydrogen ions (pH) and reduce microbial fermentation (Schingoethe et al. 2009). As well S naturally occurs in yeast at 3.9 g per kg (White and Johnson 2004). The recommended maximum S level is 0.44% of the total beef diet (NRC 2000), and if this level is exceeded there is risk that polio-encephalopathy like symptoms may occur in the animal. The S content of corn DDGS tends to be higher than wheat DDGS and levels of S in corn DDGS has been found to be over 1% (Nuez-Ortin 2010) and are variable between ethanol plants (Spiehs et al. 2002). To manage the risk of over feeding S in the diet, consideration of all water sources for S should be known. Also interaction with Molybdenum can have negative effects on other mineral absorption and should be tested for in the feed and considered when feeding elevated S.

2.3 Use of Wheat DDGS in Ruminant Diets

2.3.1 Nutritional Concerns

A nutritional concern when feeding DDGS to cattle is the potential for ruminal acidosis. It was proposed that feeding DDGS to beef cattle may buffer the incidence of ruminal acidosis due to the high fiber content of DDGS (Ham et al. 1994). This was addressed in a study done by Walter (2010), where it was demonstrated that rumen pH levels were similar for feedlot cattle fed a traditional high concentrate grain diet and a diet containing wheat and corn DDGS. When feeding wheat-based DDGS, similar considerations should be taken when feeding barley grain or any other concentrate in the ration.

2.3.2 Physical and Chemical Variability

The nutrient composition of wheat-based DDGS can be variable. This variation comes from the initial grains used for ethanol production which can vary dramatically in quality, resulting in varied chemical composition of co-products produced. This is because the co-products have proportional chemical composition to the parent grain used in ethanol production minus the starch (Belyea et al. 2004). It has been shown that different ethanol plants produced co-products that differ both physically and chemically even when using similar parent grains (Loy and Wright 2003; Kononoff and Erickson 2006; Rosentrater 2007). The reason for this may be related to the drying process and the addition of syrup to the dryer (Spiehs et al. 2002).

Wheat and wheat-based DDGS can vary in physical appearance and in density dramatically. A darker color can be associated with Maillard byproducts and decreased protein availability (Cozannet et al. 2010). The density of the co-product can have huge logistical consequences. Some ethanol plants produce a very low density, fluffy co-product while other plants produce a higher density co-product known as high density rounds called syrup balls. Figure 2.2 indicates how wheat-based DDGS can vary in both color and density depending on the ethanol plant of origin.

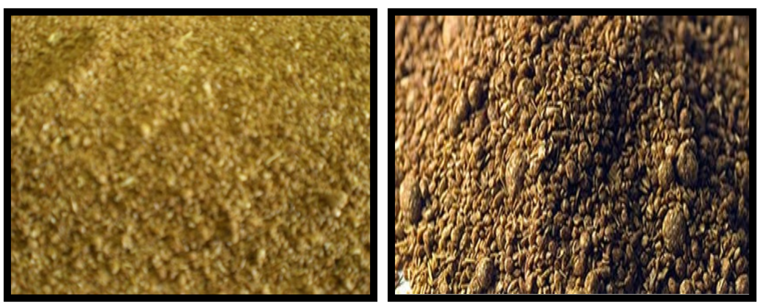

Fig. 2. Comparison of wheat based DDGS obtained from Nor-Amera Bioenergy at Weyburn, SK (left) and from Husky Energy at Lloydminster, SK, Canada (Adapted from www.ddgs.usask.ca)

2.3.3 Environmental Concerns

The chemical composition of DDGS may lead to cause for concern regarding the impact on the environment when fed in ruminant diets at high levels. Environmental concerns regarding the feeding of DDGS are the elevated crude protein content resulting in increased excretory Nitrogen (N) and the high P content resulting from increased excretion in the feces. Fecal N and P can act as an alternative fertilizer source but can also be harmful to the environment if leached into surface or ground water. Carpenter et al. (1998) explains that the combination or individual leaching of N and P into surface waters can cause toxic algal blooms, and loss of oxygen, resulting in plant and fish death and loss of biodiversity. These issues can be addressed by ensuring that manure from drylot pens is spread onto fields and not collected in areas where leaching into groundwater is a concern.

2.4 Stocker Programs

The term stocker program can be synonymous with backgrounding programs (Peel 2003). Stocker production typically consists of managing calves after weaning and adding weight for a period ranging from 3 to 6 months (Peel 2003; Klopfenstein et al. 2001; Rasby et al. 1994). Thompson and White (2006) describe this period as the phase between weaning and finishing. Alternatively, Peel (2003) describes the stocker industry as difficult to describe, as it cannot be defined based solely on the age of cattle, class of cattle, size of cattle or cattle production system. Depending on the operation, stocker programs may differ in the breed of cattle used, starting weight, targeted gains, and feeding programs implemented. Therefore stocker programs can be identified and defined by a few common characteristics as described by Peel (2003). The first is that the program is based on managing cattle growth in the form of skeletal frame and muscle development. This means that minimal fat deposition is targeted during this growing period (Perillat et al. 2004; Peel 2003). Secondly the diets used are generally forage based rations (Klinger 2005; Beauchemin and Mc Ginn 2005). And finally, the program must be a viable economic enterprise meaning that this phase of production can be considered a business where the financial outputs exceed the monetary inputs.

Stocker programs are usually centered on a high forage based ration (Peel 2003; Pond et al. 2005). These forage-based gains during backgrounding are the least expensive and contribute to the cost competitiveness of the beef industry (Peel 2003). The goal in beef cattle production is to maximize production efficiency. The efficiency of production involves optimizing both production or growth while taking into account the production costs (Pond et al. 2005). Often forage based rations provided on pasture can help producers to maintain a healthy balance of obtaining optimal production and economic efficiency.

Typically, stocker programs take place all year round, both in drylot and pasture systems. Recently, year round pasture based systems have received attention in western Canada due to the potential for decreased costs (Kelln et al. 2011). An obstacle with year round production is compensating for inconsistent forage quality fed to the animals (McCartney et al. 2008a). Therefore, supplementation must be provided to account for forage quality deficiencies. Forage quality can vary with maturity, nutrient availability and climate (Huston and Pinchak 1991). In general, there are more opportunities for grazing during spring and summer months but availability of stocker cattle is usually the highest in the fall because most calves are born in the spring (Peel 2003). This means that many stocker programs must incorporate fall and winter management plans.

It has been estimated that winter feed costs account for 60-65% of the total cost of production on a cow calf operation (Kaleil and Kotowich 2002). Alternative winter feeding systems such as swath grazing, crop residue grazing and bale grazing have shown to effectively reduce the costs associated with winter feeding (McCartney et al. 2004a). McCartney et al. (2004a) compared drylot feeding cows to a swath grazing program and reported no negative effects on calving interval, calving span, open cows and cull rates between systems.

2.4.1 Intensive versus Extensive Stocker Systems

Typically stocker programs focus on extensive pasture systems. However there are also programs that are based on confined drylot systems (Thompson and White 2006; Peel 2003). Intensive systems are represented by confined housing along with more inputs and more infrastructure requirements (Anderson and Boyles 2007). Intensive systems can allow for more efficient use of forage in the diet, increased production per unit of land, easy monitoring of animal performance, and the advantage of “bunk breaking” animals before feedlot introduction compared to extensive systems (Anderson and Boyles 2007). In contrast, extensive stocker systems provide more space per animal, have lower risk of disease, require less inputs due to labour and manure hauling costs, and require a lot less infrastructure. Extensive pasture grazing options for backgrounding calves are becoming popular for these reasons. A distinct advantage of extensive systems is the lower potential production cost and cost of gain. When the forage is grazed in field paddocks where it is grown, additional savings are achieved as the costs involved with harvesting and transporting the feed and manure are eliminated (Sask Forage Council 2011).

Current literature comparing the economics of extensive versus intensive stocker programs report that extensive systems can result in lower cost of production (Kelln et al. 2011; Kumar 2010). Kumar et al. (2010) conducted a trial comparing wintering calves in drylot pens to calves grazing either swathed barley or swathed millet. The authors found that cost of gain was 30% less for the calves grazing swathed barley compared to the drylot management and contributed these saving to a 54% reduction in yardage costs and lack of manure removal costs. Similarly, Kelln et al. (2011) compared total production costs of 4 different winter feeding systems; bale grazing, swath grazing, crop residue grazing and drylot pen feeding. The authors concluded that over a 3 yr period, swath grazing costs were $0.76 per cow per day, while bale grazing and straw chaff grazing resulted in total costs of $0.98 and $1.27 per cow per day, respectively. Drylot fed cows had total costs of $1.07 per cow per day. This resulted in a 29 and

8% savings for swath grazing and bale grazing respectively compared to a drylot feeding system (Kelln et al. 2011).

2.4.2.1 Extensive Winter System

Rasby et al. (1994) reviewed the rate of body weight gain targeted when managing calves in fall winter stocker programs. Three targeted gain ranges were discussed. The first range is a targeted gain of less than 0.45 kg per day, and assigned to cattle that will be grazed on pasture the following spring and summer. The second range is a targeted gain of 0.45 to 0.91 kg per day and is optimal for heifer development programs. These targeted gains provide a few options when marketing, as lighter weight calves can either go straight to grass or enter directly into the feedlot while the heavier calves can either be sold or placed on a finishing ration. The third range has a targeted gain of 0.91 to 1.02 kg per day where the calves are placed directly into a feedlot type system.

As most calves are born in the spring and available for backgrounding in the fall post weaning, winter management of beef calves is of major importance. Winter feeding costs are a major contributor to the overall cost of production for cow-calf producers (Taylor 2008). Evaluating the cost of production for 22 beef producers in Saskatchewan with an average herd size of 282 cows, Larson (2010) reported that winter feed and bedding costs were $1.32 per cow per day whereas the cost of grazing was $0.70 per day. These results demonstrate any management strategies that can be used, should be considered.

There are several options when managing stocker calves in extensive winter systems and can include bale grazing, crop residue grazing and swath grazing. Bale grazing is where round hay bales are placed in the fall on a field site for animals to graze in fall and winter months (McCartney et al. 2004a). Swath grazing and crop residue grazing usually involves a variety of annual forages. Whole plant swaths or crop residue (straw- chaff) piles are left on the field for animals to graze throughout the winter months (Surber et al. 2001 ; Krause et al. 2012). Due to cold winter temperatures water availability can be a concern. However, it has been shown that beef cows can snow graze in these extensive winter pasture systems with no negative effects (Degan and Young 1991; Degan and Young, 1990 a;1990b). In contrast, when managing beef calves in field paddocks in winter, water should be provided. In some cases more than one winter system may be adapted to extend the winter grazing period. These winter programs may include either one or several extensive systems along with a drylot based system depending on forage availability, forage cost, environmental issues and overall management goals. Extensive winter systems have been evaluated in several western Canadian studies (McCartney et al. 2004a Van De Kerckhove et al., 2011; Kelln et al., 2011; Krause et al., 2012;).

Forage based diets can be deficient in protein and energy during winter, therefore restricted growth may result which is followed by subsequent compensatory gain the following summer (Jordan et al. 2001). Some stocker programs are designed to restrict the animal's growth to a certain targeted level. When conducted properly, growth restriction can result in desired compensatory gain when animals are placed on pasture or when they enter a feedlot facility (Klopfenstein et al. 2000). Compensatory gain is the time following a period of nutritional deprivation when the previously deprived animals grow more rapidly than those whose diets have not been deprived (t'Mannetje 1978). A 2 yr summary conducted by Jordan et al. (2001) compared compensatory gain experienced by animals that were wintered at different rates of gain. They found that calves wintered at 0.68 kg/day (1.5 lb/day) of gain had lower slaughter breakevens ($P<0.05$) than animals wintered at 0.23kg/day (0.5 lb/day) gain. The animals kept at a lower rate of gain (0.23kg/day) through the winter had significantly ($P<0.05$) higher rates of gain in the summer compared to animals that gained more in the winter. The rates of summer gain while managed together on the same pasture was 0.58 kg/day for the animals that gained 0.68 kg/day in the winter compared to 0.65kg/day summer gain for the animals that gained 0.23kg/day in the winter.

Klopfenstein et al. (2001) performed an experiment to determine compensatory growth following the wintering of animals grazing crop residues. They reported that the group of animals that gained the least during winter had the greatest compensation in the summer months. It was concluded that the more restricted animals made up 88% of the gain, which they didn't achieve in winter throughout the summer months.

Several studies evaluating the rate of compensatory gain post winter restriction have been conducted by Klopfenstein et al. (2001) and the following conclusions were made; i) Compensatory gain on grass is variable and difficult to predict; ii) Longer restriction period may reduce compensatory gain; iii) A full season of grazing achieves 40 to 45% compensatory gain on average and; iv) Compensatory gain can be explained by intake of net energy of gain (NEg) above maintenance requirements.

2.4.2.2 Extensive Summer Systems

Extensive summer backgrounding systems for beef cattle are managing animals grazing various pasture forages. Forage types include early growth annuals, perennial grass or legume species, dormant native rangeland, and crop residues (Pond et al. 2005).

A planned schedule of pasture use is one that defines when and where livestock will graze during the season to accomplish the desired goals set out by the manager (Abouguendia and Dill 1993). It is important when planning a grazing system to remember that stocking rates and grazing densities can directly influence forage production and animal performance

(Vallentine 2001). Implementing a grazing system is the best way to utilize and plan for efficient forage utilization from both an animal performance and available forage production perspective.

Typically, implementing a grazing plan involves taking an inventory of available forage and making a plan that compliments the forage species available (Lodge, 1970). Cool season species or earlier maturing plants are known as C_3 plants. Common C_3 annual crops include spring cereals such as barley (*Hordeum vulgare*), wheat (*Triticum aestivum)*, triticale (*Triticosecale)* and oats (*Avena sativa*). Warm season crop known as C_4 plants, are later maturing and include millet (*Pennisetum glaucum*), corn (*Zea mays*) and sorghum (*Sorghum bicolor*). The division of C_3 and C_4 plants, stems from the difference between photosynthesis and the C_3 versus C_4 pathway of carbon fixation (Hobbie and Werner 2004). Both cool and warm season forages can be managed together to complement each other due to the different growing cycles and therefore differing time of optimal production for grazing (Holechek et al. 2004; McCartney et al. 2009). Complimentary grazing can also be used where an early maturing grass such as crested wheatgrass (*Agropyron cristatum*) is grazed early followed by native pasture later in the grazing season (McCartney et al. 2004a). Native pastures are typically grazed later in the season to allow the native grasses to flower before use (Holechek et al. 2004). Another example of complimentary grazing includes forage mixtures within the same stand that compliments the nutritional needs of the grazing animals. An example of this would be incorporating alfalfa (*Meticago sativa*) with grass species to increase the CP value of the forage stand. Alfalfa has been bred for increased yield, nutritive quality and to grow in a variety of environments (Berg et al. 1999). Alfalfa is known for its high protein content and high rate of gain achieved by cattle grazing the crop (Campbell 1963; VanKeuren and Heinemann 1957). However, perennial species must be chosen carefully due to reductions of dry matter yield and quality over the grazing season (Ocumpaugh and Matches 1977). These losses can largely occur in alfalfa with leaf loss resulting in both reduced yield and quality (Baron et al. 2004).

Other non-bloating legumes include birdsfoot trefoil (*Lotus corniculatus*), sainfoin (*Onobrychis viciifolia*) and cicer milkvetch (*Astragalus cicer*). These legumes are not as common as alfalfa due to their lack of grazing tolerance and competition when established in a mixture with grass species. For cold winter environments such as in Saskatchewan, winter hardiness with these non-bloating legumes can be a problem.

2.4.2.3 Extending the grazing season

In western Canada, most forages used to extend the grazing season are cool season or C_3 species. Because of this, late summer and fall forage biomass availability may be limited (Barnes et al. 2003). The combined management strategies of grazing annual cereals and grazing stockpiled perennials have been shown to effectively extend the grazing season (McCartney et al. 2004a). Extending the grazing season using stockpiled perennials is when forages are not grazed throughout the summer and grazed only in the fall and early winter. This requires careful management to make use of the forage in a way that optimizes both timing of grazing and plant nutritive value (Scarbrough et al. 2004). When implementing this system both warm and cool season forages can be used, however, cool season forages tend to have better nutritive value in cooler temperatures compared to warm season forages (Lacefield et al. 2006).

Annual crops are great options for extending the grazing season (McCartney et al. 2008a). Annual crops are easy to seed, establish quickly and can provide pasture later in the growing season when perennial production is decreasing and demand is at its highest (McCartney et al. 2008a). Spring seeded cereals do not grow well after being grazed as the position of the growing points or apical meristems are elevated on the mature plant which results in defoliation, followed by slow regrowth (Richards et al. 1988). Depending on management goals, one method for extending the grazing season may be late season grazing of annual cereals such as fall rye (*Lolium multiflorum*), winter wheat (*Triticum hybernum*) and winter triticale (*Triticale hexaploide*) when plant are no longer in a vegetative state and temperatures are cooling (McCartney et al. 2008a). Seed costs may be higher, however annuals can provide better quality forage during late summer, fall or early spring. Stocker programs are designed to add value to calves using the cheapest feed source available (Peel 2003). Annual cereals have been shown to be a profitable addition to stocker rations and can be used as an excellent strategy to extend the grazing season (Todd et al. 2007).

2.5 Supplementation in Backgrounding Programs

Supplementation involves providing grazing animals with additional energy or protein to increase the nutrient intake of the animals (Allden et al.1981). Supplements are commonly provided to grazing animals when available forage cannot meet the requirements of the animals or provide enough energy to the animals to meet targeted gains. Supplementation type can vary depending on the available forage and production goals (Pond et al. 2005). In some cases the forage alone provides enough nutrients to meet the targeted goals. In these situations the only required supplements are vitamins and minerals. Rasby et al. (1994) explains that targeted gains of 0.23 to 0.45 kg/day may be achieved by feeding only roughages to provide the protein and energy requirements of the animal. In some cases there are roughages that will provide sufficient energy that may allow animals to exceed the targeted gain (Rasby et al. 1994). Therefore it may be required to restrict some roughage types when gains are targeted to less than 0.45 kg/day.

Climatic and metabolic fluctuations can dramatically change the daily requirements of the grazing animal (Young 1975). NRC (2000) explains that net energy for maintenance (NE_m) requirements for animals at thermal neutrality is related to the previous ambient temperature and can be estimated using the following equation (NRC 2000):

Equation 2.1 $$NE_m = (.0007*(20 - Tp)) + 0.077 \quad Mcal/BW^{0.75}$$

Where NE_m is net energy of maintenance; Tp is previous ambient air temperature; BW is body weight and Mcal is Mega calories.

This means that for every one degree the temperature differs from 20 degrees Celsius, the requirements of the animal differs by 0.0007 $Mcal/BW^{0.75}$. National Research Council (2000) states that the temperature starts to effect dry matter intake (DMI) are those above 25°C and below 15° Celcius. Typically DMI increases in colder temperatures and decreases in warmer temperatures (Young 1975), therefore these temperatures will influence animal energy status and should be accounted for when formulating rations. Table 2.1 indicates the lower critical temperatures of animals with varying pelage (hair coat).

Table 2.2. Lower critical temperatures for beef cattle, assuming no wind.

Coat Description	Lower Critical Temperature	
	°F	°C
Summer Coat or Wet Coat	59	15
Fall Coat	45	7
Winter Coat	32	0
Heavy Winter Coat	18	-8

*(Adapted from Tarr 2007)

There are factors that must be taken into account when choosing the proper supplement. One factor is the feed type as ruminants can take low quality protein sources and improve protein quality through microbial synthesis (Milton et al. 1997). At different physiological stages of development cattle have differing nutrient requirements (NRC 2000). Either a protein supplement or an energy supplement can be supplied depending on the requirements of the growing or breeding animal (Peel 2003). To receive the most efficient growth possible it is essential to provide the animal the proper protein to energy ratio to maximize microbial protein synthesis (Van Soest 1994). Another consideration when supplementing is called the substitution effect. This is when a supplement is offered and instead of supplementing to increase intake of the available forage, the supplement substitutes part of the total forage DMI with the supplement itself (Hacker 1982). The substitution effect can cost money because supplementation is typically more expensive than providing a forage source.

Supplementing yearling animals both on pasture and in drylot can be a difficult task especially when trying to regulate individual animal DMI as well as considering optimal supplementation levels regarding optimal rumen fermentation and forage use (Van Soest 1994). Van Soest (1994) explains that this problem can mostly be attributed to the mismatch of protein and energy that is typically found in a supplement.

There are several different methods to supplement animals grazing pasture. One method is to feed the different types of grain, pellets or range cubes on the ground in such a way that all animals can have access. It has been found that consistent morning delivery of the supplement works to achieve the most efficient intake of the supplement (Hacker 1982). Portable troughs can also be used to decrease supplement waste. Another method is using different types of molasses based lick tubs, some of which contain a protein source. Liquid supplements such as urea are easily delivered when mixed with solid feedstuffs or milling byproducts such as hulls for delivery to the grazing animal. Finally, successful supplementation is dependent on palatability of the supplement provided and the ability of the supplement to be distributed evenly among the animals at the bunk.

2.5.1 Protein supplementation

The net supply of protein to the ruminant animal is a complex interaction of the diet, microbes and the host (Van Soest 1994). Protein supplementation depends on nature and amount of protein as well as the amount of carbohydrate contained in the forage source (Pond et al. 2005). Ruminants are flexible in the form and quality of protein that they receive as they have the ability through the microbial population to convert cheaper non-protein nitrogen (NPN) sources into a good quality microbial protein that can then be metabolized (Van Soest 1994; Milton et al. 1997). Common NPN sources for beef cattle include urea, biuret, ammonium salts and a variety of ammoniated products (Stanton and Whittier 2010). Fiber digestion in the rumen depends on bacteria to break down the ß-1,4 linkages (Van Soest et al. 1991). Therefore it is important when feeding forage based rations to provide the bacteria with an adequate amount of N (Koster et al. 1996).

There are limitations on feeding different nitrogen sources. If the N source is rapidly converted to ammonia (NH_3) and transported into the blood, it can reach a level that is toxic to the animal (Reece 2015). Urea, a common NPN source usually contains 46.7% N and the level of urea is recommended to not exceed more than 20 to 33% of total N in diet (Stanton and Whittier 2010). It is also important when using a NPN source to feed the supplement in conjunction with a readily fermentable carbohydrate source (Pond et al. 2005). This is so the rumen microbes can synthesize the NPN into protein using the carbon skeletons of the carbohydrate to decrease the chances of toxicity and to increase the efficiency of the rumen (Johnson 1976). It is recommended that animals under 204 kg do not receive urea as a protein source (Stanton and Whittier 2010). Rasby (1994) warns that although it is possible for cattle under 272 kg to use NPN sources, it was reported that plant protein fed calves gained better due to a more efficient use of the protein source received.

Other supplements known for high protein levels include soybean meal, canola meal, DDGS, and corn gluten meal. These sources along with others can be part of a supplementation plan to meet targeted gains while obtaining a balance of economic and production efficiency (Pond et al. 2005).

In a study by Beaty et al. (1994), cattle consuming low quality forages were supplemented with different protein levels at differing frequencies. They found that intake of wheat straw tended *(P*=0.06) to increase quadratically with increasing CP concentration in the supplement. Supplementing cattle daily compared with supplementation occurring three times a week also increased *(P*<0.01) straw DM intake. Peak DMI intake of straw was observed for the group receiving a 30% crude protein. This study indicates that to get the most from the available low quality forage it is best to feed animals a source of protein supplement daily. The study also demonstrated that above a certain threshold, more CP did not show the same benefits of forage digestion. A study conducted by Grings et al. (2004) who fed yearling cattle a barley and soybean meal based protein supplement in late fall on pasture found that forage at the start of season was above 7.5% CP and decreased during the grazing season in all 3 years. In the last 2 years of the study, CP level dropped to 5% by the end of the study. The treatments included a control group fed no supplement, one group was supplemented with 25.8% CP and another supplemented with a 40% CP supplement. The supplemented animals were provided 1.62 kg per head every third day. The authors found that body live-weight gain, forage intake and digestibility were not affected by supplementation. This suggests that in some cases it may be wasteful to feed a supplement, if the level is not high enough to improve animal performance.

2.5.2 Energy Supplementation

Cereal grains are the primary energy supplement fed to cattle on the western Canadian prairies. Energy supplementation must be done carefully and at a level that does not interfere with roughage digestion. Cereal grains are noted for their ability to decrease the rate of fiber digestion, and this can result in decreased intakes and subsequent decreased weight gains (Hess et al. 1996; Rasby et al. 1994). An effective way to decrease the negative effects that energy supplements tend to exhibit on roughage digestion is to feed high energy fibrous by products such as soyhulls, gluten feed or and beet pulp (Rasby et al. 1994). Dried distillers grains can also be categorized as energy supplements. Dried distiller grains plus solubles have a higher fat content and a fiber fraction that is highly digestible and very comparable to barley grain (Walter 2010). Energy supplements are extremely important when fed in combination with protein supplements. As described earlier, microbial manipulation and synthesis of protein requires energy especially if efficient conversion of protein is desired (Hess et al. 1996). A study by Royes et al. (2001) found that when feeding ammoniated hay, energy supplement of corn, soybean hulls, and molasses increased the digestibility of the hay. Apparent organic matter (OM) digestibility increased in a linear manner with increasing feeding rate of soybean hulls (P = 0.003) or corn (P = 0.007) and increased in a quadratic (P = 0.02) manner with increasing level of molasses supplementation (Royes et at. 2001). This study demonstrates the need for energy supplementation with a N source. The best increase in digestibility was observed from the supplementation of soybean hulls. This would be expected as the soybean hulls would provide the greatest source of carbon skeletons to the microbes to make the most efficient use of the ammoniated hay.

In a supplement study by Lake et al. (1974), calves were fed on irrigated orchard grass (*Dactylis glomerata L.*) and smooth brome grass (*Bromus inermus*) hay. It was found that energy supplementation increased body weight gains in a linear manner (P >0.05) in both trials conducted. The animals were supplemented a pelleted mixture of 94% corn, 5% sugar cane, molasses and 1% pellet binder which was individually fed at 0.0, 0.45, 0.91, 1.36, 1.82, 2.27 and 2.72 kg per head daily. A similar trial with a corn based supplement in the first year found that in both trials, supplementation above 1.82 kg (4 lb) per day did not improve gain indicating this may be near the maximum amount of supplemental energy justifiable (Lake et al. 1978).

2.6 Methods of Determining Pasture Production

2.6.1 Methods of Determining Intake on Pasture

Measuring forage intake is extremely important especially when evaluating a supplement given to pasture animals and looking at digestibility parameters (Mertens 1987). There are many methods for evaluating forage intake of grazing animals. These methods can be partitioned into two categories 1) Direct measurement; and 2) Indirect measurement.

Direct measurement of forage intake on pasture can be done by either weighing the animals or monitoring the animals on pasture (Burns et al. 1994). Weighing the animals involves weighing them before and after grazing. This method can include non-forage associated errors which affect weight change such as water intake, supplement intake, and other daily metabolic functions. There are also errors associated with converting actual weight change to forage intake on a DM basis (Minson 1990). This method would be hard to extrapolate to a trial that runs over a longer period of time and may not be representative of voluntary intake due to stressors during the weighing process (Minson 1990). Monitoring animal intake usually requires an intake technique or measuring bite counts (Van Soest 1994). The error associated with this method is the bite count is a product of number of bites times bite mass (Van Soest 1994). And bite mass is not easily estimated and can differ depending on a variety of animal and forage factors (Minson 1990).

Indirect measurement of forage intake is typically conducted using 1 of 3 techniques. The most common is using fecal indices which can be attained when determining digestibility on pasture. Others are forage utilization and prediction equations. Langlands (1975) suggested that an experiment with penned animals may assess metabolic and production characteristics of forages but this type of experiment would have a hard time estimating DMI compared to that of a grazing ruminant. This may also be difficult as one considers that Van Soest (1994) suggests that the nutritional requirement of a grazing animal can be up to 120-140% that of a penned animal.

Forage utilization can be measured by using several different techniques as described by Van Soest (1994). The most common methods are using a trained individual to estimate the percentage of herbage removed by animals via visual observation, weight measurement of forage before and after animal introduction in several small plots and estimation of forage disappearance by measuring forage height before and after grazing. Each method described has areas for improvement and error. If done quickly, efficiently and replicated enough times randomly throughout a pasture these methods can be used as a valuable tool for estimating forage dry matter intake.

Prediction equations are also a valuable tool when estimating forage intake on pasture. It can be of particular use when used in conjunction with another method to verify intake such as with a forage utilization estimate (Van Soest, 1994). There are many prediction equations that have been developed to help attain an estimation of intake. Prediction equations take into account at least one of the following factors, the diet of the animal, animal characteristics and environmental observations. Some equations are quite involved and require collaboration of many prediction equations and accurate input of the information regarding environment, nutrient intake composition, and animal factors (Fox et al. 2004). Programs such as CNCPS can make estimates based on available prediction equations and entered data but can also involve error with respect to data entered and natural fluctuations that occur between estimation and reality (Fox et al. 2004). Some of the DMI prediction equations can be as simple as relating intake to a specific nutrient composition. For example, Mertens (1987) developed an equation that simply related intake to the NDF content of forage using the following equation (Mertens 1987).

Equation 2.2 Dry matter intake (DMI) = (1.2% x BW) / (% NDF)

(Metens 1987)

Where BW is body weight and NDF is neutral detergent fiber.

2.6.2 Measuring Digestibility on Pasture

Measuring the digestibility of individual feedstuffs has proven invaluable for beef nutritionists and scientists. It allows for accurate efficient formulation of rations and has led to improved feeding methods throughout the beef industry (Pond et al. 2005). Measuring digestibility in a pen designed experiment has proven to be quite easily attained and accurate (Pond et al. 2005), however, on pasture it is more difficult. Apparent digestibility refers to the amount of feed nutrients that is apparently absorbed by the gastrointestinal tract (Pond et al. 2005). Digestibility can be measured with 3 methods which are *in vivo*, *in situ*, and *in vitro* techniques.

For *in vivo* studies where animals are kept in a facility that facilitates the exact measurement of DMI and fecal output, a simple digestibility equation can be used such as the one reported by Van Soest (1994);

Equation 2.3 (Digestibility (%) = [(Intake-Feces)/Intake] x 100)

(Van Soest 1994)

In the event that feces collection is not easily done, indigestible markers can be used to estimate fecal output and digestibility (Van Soest 1994).

Different markers can be used to evaluate digestibility and are classified as either external or internal marker and should follow a few key criteria; they should not be absorbed by the animal, must follow the digesta, be easy to dose and easy to determine (Owens and Hanson 1992). Digestion can be calculated with markers using the following equation (Cochran and Galyean 1994; Van Soest 1994):

Equation 2.4

Digestibility (%) =100-100X[(marker in feed/marker in feces) X (nutrient in feces/ nutrient in feed)]

(Cochran and Galyean 1994; Van Soest 1994)

Internal markers are those that are found in the feed or animal itself such as silica, lignin, acid insoluble ash (AIA), chromogen, cellulose, and alkanes (Owens and Hanson, 1992). Research has demonstrated that the AIA technique is easily used, more accurate than lignin and more correlated to total collection trials (Van Keulen and Young, 1977). External markers are not found in the feed naturally and have to be either attached to the feedstuff or dosed in the animal. Common external markers are metal oxides, rare earths and isotopes (Owens and Hanson, 1992).

In situ methods of determining digestion are centered around the *in sacco* or nylon bag degradation method. This method involves feed samples being left in the rumen inside porous nylon bags for varying lengths of time. These methods are used to determine rumen degradation kinetics and can be further extrapolated via wet chemistry and equations to determine feed digestibility (Orskov et al. 1980). *In situ* methods can be affected by a variety of factors including cow base diet, sample preparation, sample density in bags, sample density in rumen washing procedures and bag influences (Orskov et al. 1980). This technique has proven very valuable when looking at the different digestive parameters of a feedstuff in regards to rumen kinetics.

Analyzing feed digestibility using the *in vitro* technique can save time, labour, and money. The most accepted *in vitro* techniques are those based on the Tilley and Terry (1963) two stage digestibility measurement. The first stage is comprised of rumen fluid digestion of the forage sample simulating rumen digestion. This stage involves the collection of rumen fluid from a fistulated donor animal. Therefore, reproducibility of this method can be interfered by the source of the rumen fluid as diet and animal characteristics of the donor animal can affect the composition, viability and overall effectiveness of the fluid (Iantcheva et al. 1999; Adesogan et al. 2000). The second stage following the simulated rumen digestion, is with pepsin digestion which mimics the acidic digestion and breakdown of feedstuffs in the lower tract or abomasum (SPARC 1998; Troelsen 1966).

2.6.3 Measuring Animal Performance on Pasture

Several techniques exist for measuring stocker performance on a pasture based trial. The first is to measure body weight (BW) change. This can be done by weighing animals at the beginning and the end of trial and at certain intervals throughout the duration of the trial. It is important to account for fluctuations in weight that are not corresponding to actual body weight changes. Fluctuations in weight that are not related to actual body weight change can be a result of rumen gut fill, water intake, feed intake patterns, and environment (Coates and Penning 2000). These fluctuations are noted and typically addressed by following consistent routines on the days the animals are weighed. Routines should be followed for everything within the control of the individual running the trial and can include but are not limited to, such as time of weighing, time of supplementing, time of watering, time of feeding, and stress during weighing (Coates and Penning 2000). The goal of determining an accurate weight of the animal is to measure the shrunk body weight. This can be done by simply withholding feed and water for a specific time or can be done by correcting the weights using equations or set adjustment factors (Coates and Penning 2000; Cook and Stubbendieck 1986).

2.7 Summary

As a result of the ethanol industry in Saskatchewan there is a need to look at the use of DDGS compared to barley as a protein and energy supplement for backgrounding animals in extensive grazing scenarios throughout the year. This need stems from the increased interest and cost advantages in extensive management systems and the availability of DDGS locally. The diversity of backgrounding management systems stems from feed availability, climate, infrastructure and resources available to managers. Because of this, there are a variety of ways and feedstuffs that can be used to support successful backgrounding programs. Typical backgrounding diets in Saskatchewan are comprised of base 60-70% forages with the rest of the diet composed of a concentrate source such as barley or other grain types (Klinger 2005; Beauchemin and McGinn 2005). The hypothesis of these experiments is that wheat DDGS will be a suitable replacement for barley in backgrounding rations.

3.0 Effect of supplementing wheat DDGS to stocker calves on fall pasture

3.1 Introduction

Kaliel and Kotowich (2002) estimate that winter feeding costs account for 60-65% of total production costs for cow calf producers. Therefore any savings made in the area of feed can make a difference on total cost of production. There has been much research focused on reducing the cost of winter feeding by extending the grazing season by managing animals on pasture longer than what is considered the conventional grazing period (Johnson and Wand 1999; Riesterer et al. 2000). The use of perennial pastures to extend the grazing season often relies on forage stand management to ensure forage is available and grazed in a manner that optimizes the forage resources, taking into account forage quality at grazing and managing the forage stand for sustainability (Riesterer et al. 2000; Scarbrough et al. 2004).

Cool season forages tend to grow at lower temperatures and maintain quality longer and have good potential for regrowth or repair when being grazed in the extended spring or fall season (Baron et al, 2004). It has been widely accepted that as biomass increases and the plant matures, plant quality generally decreases. Van Soest (1994) explains that as plants age the structural integrity of the plant is enhanced mostly by cell wall components increasing. These components include soluble pectins, waxes, proteins, insoluble lignin, cellulose, and hemicellulose (Van Soest 1994). The higher presence of insoluble fiber components results in these mature stockpiled plants being of lower nutritional quality for grazing. In most cases, management when extending the grazing season into the fall must include supplementation to offset decreasing forage quality.

Typically, crested wheatgrass (*Agropyron cristatum L.*) is an early maturing grass that can be readily grazed in the spring and has been shown to provide quality forage in cooler temperatures making it an excellent candidate for extending the fall grazing season (Currie 1970). The yield of crested wheatgrass has been shown to maximize by mid-October in western Canada (Baron et al. 2004). However, this increased yield is associated with decreased forage quality resulting in the plant generally not providing adequate protein to mid gestation cows (Adams et al. 1994; Villalobos et al. 1997; Jensen et al. 2002; Baron et al. 2004) or grazing calves. Because of low protein content supplied by the forage, supplementation of grazing animals consuming this forage type is necessary.

Supplementation costs reflect a good proportion of variable costs that are associated with beef production (Stalker 2009). This is due to the volatile nature of feed grain markets and the fact that stocker calves are traditionally supplemented with cereal grains in the ration. With the expansion of the ethanol industry and increased availability, DDGS has been shown to be a comparable supplement for beef cows compared to traditionally used supplement like barley (Neuz-Ortin and Yu 2010; Van De Kerckhove 2011). There may also be an opportunity for beef producers to look at alternate supplementation strategies using wheat DDGS for backgrounding calves. As barley grain is typically used in western Canadian diets any research that compares DDGS as a supplement should include barley. The specific objectives of this research were to evaluate the performance of weaned cross-bred beef calves in an extended fall grazing program supplemented with either wheat DDGS or barley grain, to estimate DMI and to determine forage displacement due to supplementation strategy and to conduct an economic analysis for each supplementation strategy.

3.2 Materials and Methods

3.2.1 Study Site

A grazing study was conducted at the Western Beef Development Center's (WBDC) Termuende Research Ranch located near Lanigan, Saskatchewan, Canada (51º51'N, 105º02'W). The study site was an 18 ha field of stockpiled crested wheatgrass (*Agropyron cristatum L.)* which was further divided into nine, 2 ha paddocks (Appendix Table A1). On October 28, 2008, in yr 1 the trial was initiated, however after 15 d it was ended on November 13, 2008 due to freezing rain and inclement weather affecting animal access to forage resulting in no useable data. The grazing study was conducted in yr 2 from October 9, 2009 to November 24, 2009 for a total of 32 days.

3.2.2 Grazing Animal Management

Fifty-four weaned, cross-bred beef calves from the main WBDC herd were used in this study and all calves were fed a grass-legume hay for 21 days prior to start of trial starting on September 3, 2009. Calves were weaned on September 24, 2009 and were vaccinated with a *Clostridial* 8-way modified live vaccine (Covexin®-8; Schering-Plough Animal Health Guelph, Ontario Canada Inc.) and a modified live bovine viral diarrhea, parainfluenza-3, infectious bovine rhinotracheitis, bovine respiratory syncytial virus (STARVACTM 4 plus Novartis Animal Health Inc. Mississauga, Ontario Canada) and implanted with (RALGRO®, 36 mg zeranol; Schering-Plough Corp, Kemworth, NJ, USA). All calves received 30 ml of megamectin topically (Ivermectin, Novartis Animal Health Inc. Mississauga, Ontario Canada).

Calves were stratified by body weight (BW) (212 ± 1.2 kg initial BW) and randomly allocated to 1 of 3 replicated (n=3) supplement strategies and managed for a targeted gain of 0.82 kg per head per day. Initial supplementation levels in each strategy were based on BW, pasture quality and environment and were determined using CowBytes Beef Ration Balancing Program

(Version 4, Alberta Agriculture, Food and Rural Development) based on NRC (2000). Trial diets were formulated t meet animal requirements for a barley based supplement and then DDG was blended in to match the canola meal needed to meet protein requirements. Supplementation amounts were adjusted during the trial to account for changes in pasture quality and increasing nutrient requirements of the stocker cattle due to BW change and environmental conditions.

Start and end of trial BW were measured unshrunk and taken over 2 consecutive days before the morning feeding and before water access and every 14 d during the trial. Replicate groups (n=3) were allocated to 1 of 3 supplementation strategies while grazing the fall stockpiled pasture which included (1) barley+canola meal (70:30 blend); (2) barley+wheat DDGS (70:30 blend) or (3) 100% wheat DDGS. The DDGS used in this experiment was a 100% wheat blend provided by Noramera Bioenergy Corporation (Weyburn, Saskatchewan, Canada).

During the study, calves were supplemented daily at 0800 h receiving approximately 1.6 kg per head per d or 0.7% of body weight. All supplements were fed in portable troughs that were top dressed with 56 g per head per d of a commercial 2:1 mineral (Feed-Rite Ltd., Humboldt, Saskatchewan, Canada) that contained 20% Ca, 10% P, 60 mg/kg Se, 70 mg/kg Co, 200 mg/kg I, 3000 mg/kg Cu, 9000 mg/kg Mn, 10,000 mg/kg Zn, 3700 mg/kg Fe, 1000 mg/kg F, 1,000,000 IU/kg Vitamin A, 150,000 IU/kg Vitamin D, 1000 IU/kg Vitamin E and 56g per animal per day limestone calcium carbonate, (38.0% Ca) (FeedRite Ltd., Humboldt, Saskatchewan, Canada). Water was brought out 2 times daily so that the animals never went without.

3.2.4 Forage Utilization Estimation

The estimation of forage utilization was determined using the herbage disappearance method as described by Jasmer and Holechek (1984). In each paddock, 30 randomly distributed 0.25 m^2 quadrats were sampled at the start and end of the grazing study. Each sample was clipped to a 4 cm stubble height, bagged and dried at 55ºC for 72 h and weighed for DM determination. Estimated stockpiled forage DM intake was estimated using the herbage disappearance method (Jasmer and Holecheck, 1984). Herbage disappearance was determined using the following equation:

Equation 3.1

$$\text{Herbage Disappearance (\%)} = \frac{(\text{g DM per } 0.25\text{m}^2 \text{ available} - \text{g DM per } 0.25\text{m}^2 \text{ residual})}{(\text{g DM per } 0.25\text{m}^2 \text{ available})}$$

Additionally, an estimation of forage DMI was calculated with the following equation:

Equation 3.2

$$\text{DMI (kg)} = \frac{(\text{kg DM d}^{-1} \text{ allocated - kg DM d}^{-1} \text{ Residual})}{\text{n/ d}^{-1}}$$

Where n= number of calves per paddock and d= number of days that the paddock was grazed.

3.2.5 Environmental Analysis

Environmental data (temperature and precipitation) was collected from a Termuende Research Ranch Benchmark Site meteorological station located 2 km east of the study site. Daily minimum and maximum temperatures along with precipitation were recorded for the study at the site. Additional records were received from Environment Canada's Climate Data Online (www.climate.weatheroffice.ec.gc.ca) for Esk, Saskatchewan, approximately 6 km SE of the study site (51°48 'N, 104°51 'W). All environmental data is reported in Appendix A.

3.2.6 Laboratory Analysis

Prior to analysis all samples were dried for 48h at 55 °C and dried forage and supplement samples were then ground to pass through a 1-mm screen using a Wiley mill (Tomas-Wiley

Laboratory Mill Model 4; Thomas Scientific, Swedesboro, NJ, USA). All samples were analysed for moisture, crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), organic matter (OM), in-vitro organic matter digestibility (OMD), calcium (Ca) and phosphorus (P). Digestible energy (Mcal/kg of DM) of the stockpiled forage was calculated using the grass-legume Penn-State equation (Adams 1995) (Appendix Equation A1) and the Penn-State cereal grain equation (Adams 1995) was used for DE determination of the supplements (Appendix Equation A2).

Moisture and ash for all samples were analysed using the method outlined by the Association of Official Analytical Chemists (method 930.15 and 942.05; AOAC 2000). Crude protein (nitrogen X 6.25) was analyzed using the Kjeldahl procedure (method 984.12; AOAC 2000) using the 2400 Kjeltic Analyzer unit (Foss Tecator, Hoganas, Sweden). Neutral detergent fiber was analyzed using an Ankom 2000 Fiber Analyzer (Ankom Technology, Fairport, NY). Sulfuric acid and heat were used to analyze ADF (method 973.18; AOAC 1997). Organic matter digestibility was estimated using the Tilly and Terry (1963) method according to Goering and Van Soest (1970). Calcium and P were analyzed using the method described by Qian et al. (1994) (method 927.02 and 965.17; AOAC 2000).

3.2.7 Statistical Analysis

Data was analyzed using the Proc Mixed Model procedure of SAS (2005) as a completely randomized design with calf BW, average daily gain and intake estimations analysed as fixed effects. Differences were considered significant when $P < 0.05$ and means were separated using Tukey's multi treatment comparison (Saxton 1998).

The experimental model used was:

$$Y_{ij} = \mu + t_i + e_{ij}$$

Where μ is the overall treatment mean, t_i is the fixed effect of the *ith* diet, and e_{ij} is the error term specific to the experimental unit. The assumptions associated with this analysis include that for all observations the populations are normally, identically, and independently, distributed with equal variability within treatments.

3.3 Results and Discussion

3.3.1 Pasture Quality

Chemical composition of pasture forage and supplements used in the trial are presented in Table 3.1. A comparison of the nutrient composition of the stockpiled crested wheatgrass pasture evaluated at the start and end of the trial suggests that forage quality declined over time (Table 3.1). A decrease in CP content and increase in fiber content as the growing season advances is well documented and can be attributed to both senescence and an increase in plant maturity (Wilson 1982; Van Soest 1994; Vallentine 2001) for crested wheatgrass in the fall (Bruynooghe 1997; Baron et al. 2004). During the 32 d trial, average forage CP content decreased 3% (6.2% to 6.0%), ADF increased 3% (34.9 to 35.8%), NDF increased by 2% (65.0 to 66.1%), and OMD decreased 2% (48.1 to 47.1 %). According to nutrient levels needed for beef calves in NRC (2000) the pasture forage did not supply sufficient CP for the stocker calves used in this trial targeted for a targeted gain of 0.8 kg per day. Using the equation developed by Adams (1995) the calculated TDN value based on ADF content for the crested wheatgrass forage was 62.3% at start of the trial and 60.4% at the end of trial, averaging 61.3%. For the body weights and growth of the cattle used in this trial, NRC (2000) recommends that these stocker calves would need to be provided a diet containing 60% total digestible nutrients. According to the forage analysis, supplementation was needed to meet all of the nutrient requirements of the calves used in this study, especially as the weather became colder as the trial period advanced.

Table 3.1 Nutrient composition of stockpiled crested wheatgrass pasture and supplements.

Item	(%, DM Basis)[z]							
	DM	CP	ADF	NDF	OM	OMD	Ca	P
Stockpiled forage								
Overall average								
Average	68.4	6.2	34.9	65.0	92.7	48.1	0.45	0.08
Minimum	59.9	5.6	31.7	60.7	92.2	44.1	0.37	0.06
Maximum	78.5	7.0	36.7	68.2	93.8	52.4	0.57	0.10
SD	6.7	0.4	1.2	1.7	0.4	1.9	0.06	0.01
n	540	18	18	18	18	18	18	18
Start of trial								
Average	55.8	6.3	34.0	63.9	92.7	49.0	0.47	0.08
Minimum	46.3	5.8	31.7	60.7	92.3	46.3	0.38	0.07
Maximum	67.1	7.0	35.2	66.0	93.7	52.4	0.57	0.10
SD	7.31	0.4	1.1	1.5	0.4	2.0	0.06	0.01
n	270	9	9	9	9	9	9	9
End or trial								
Average	81.0	6.0	35.8	66.1	92.8	47.1	0.4	0.07
Minimum	73.5	6.6	36.7	68.2	93.8	49.0	0.5	0.09
Maximum	89.9	5.6	35.2	65.1	92.2	44.1	0.4	0.06
SD	6.1	0.3	0.4	1.0	0.5	1.4	0.1	0.01
n	270	9	9	9	9	9	9	9
DDGS[y]	89.9	36.4	17.1	44.6	95.5	69.1	0.10	0.78
Barley	89.1	15.0	7.2	23.9	97.5	81.1	0.06	0.40
Canola meal	90.2	37.4	20.2	30.8	93.2	75.0	0.81	1.11

[z]DM= percent dry matter; CP= crude protein; ADF= acid detergent fibre; NDF= neutral detergent fiber; OM=organic matter; OMD= organic matter digestibility; Ca= calcium; P=phosphorus.
[y]DDGS= dried distillers grains with solubles.

3.3.2 Forage Utilization and Estimated Intake

Forage utilization and estimated DM intake of stockpiled forage and supplements are presented in Table 3.2. There was no difference ($P > 0.05$) in forage utilization or calculated DMI between the three supplemented groups. Grazing ruminant response to supplemental protein is usually observed when the CP content of the basal diet is less than 6 to 8 % (DelCurto et al. 2000). In the current study, stockpiled crested wheatgrass forage CP content ranged from 5.6 to 7 percent (Table 3.1). The DDGS supplemented calves did have numerically greater pasture utilization and forage DM intake compared to the other supplemented groups. This suggests that substitution was not a factor for one supplement compared to another supplement in the current study. A factor that may have influenced the greater numeric forage DMI of the DDGS supplemented calves is the effect of protein supplementation, which has been shown to increase forage DM intake in some situations (Pond 2005; Koster et al. 1996; Beaty et al. 1994; Van Soest et al. 1991). In the current study, the ration that included the 100% DDGS supplement oversupplied CP compared to the NRC (2000) requirements for a 204 kg calf gaining 0.82 kg per day. The CP content of forage was highest for the DDGS supplemented calves (14.4%), moderate for the control calves (12.2% CP) and lowest for the Barley: DDGS calves (10.0% CP). Similar to the estimated forage DMI, the DDGS supplemented calves had the greatest numerical utilization of pasture forage (Table 3.2). Although not statistically significant in the current study, the effect of protein supplementation increasing estimated forage intake is also supported by other studies (Hennessy et al. 1985; Caton 1988; Beaty et al. 1994; Mathis et al. 1999; Bandyk et al. 2001).

Table 3.2 Effect of supplement strategy on forage utilization and estimated DMI of forage and supplement

Item	Control	DDGS[x]	70:30	SEM[y]	P-Value
Available forage (kg/ha)	2074.1	2180.0	2096.7	51.9	0.49
Residual forage (kg/ha)	1832.5	1727.4	1762.0	51.12	0.22
Consumed (kg/ha)	288.2	452.6	334.7	83.47	0.41
Utilization (%)	9.6	20.8	15.7	0.40	0.41
Estimated intake (kg/hd/d)					
Supplement	1.6	1.6	1.6	-	-
CWG[z]	3.0	4.8	3.5	0.85	0.40
Total	4.6	6.4	5.1	0.85	0.42
Estimated intake (%BW/hd/d)					
Supplement	0.7	0.7	0.7	-	-
CWG	1.4	2.1	1.6	0.40	0.43
Total	2.1	2.9	2.3	0.40	0.44

[x]DDGS = dried distillers grain plus solubles.
[y]SEM = pooled standard error of the mean.
[z]CWG= crested wheatgrass.

3.3.3 Calf Performance

When comparing supplementation strategies fed to calves grazing fall pasture there were no differences (P > 0.05) on calf final BW, BW change or average daily gain (ADG) (Table 3.3). However, the calves receiving 100% DDGS as a supplement had numerically higher ADG when compared to the barley supplemented calves and the 70:30 supplemented calves.

As mentioned previously diets were formulated to meet the requirements of the growing calves for a targeted gain of 0.82 kg per day. However, the daily gain achieved by each treatment group of calves averaged 0.62 kg per day, suggesting that there may have been other factors limiting the growth of these animals. The daily temperatures during the study period ranged from 6.9 to -5.7°C with an average temperature of 0.6°C (Table A.1).

Table 3.3 Effect of supplementation on calf performance grazing fall pasture

Item[z]	Control	DDGS	70:30	SEM	*P-value*
Body weight					
Initial (kg)	205.2	205.6	206.6	0.80	0.66
Final (kg)	225.8	228.3	225.2	2.34	0.61
Change (kg)	20.7	22.6	18.6	2.13	0.44
Average Daily Gain (kg/d)	0.63	0.68	0.56	0.50	0.50

[z]DDGS = dried distillers grains plus solubles; 70:30 = 70% barley and 30% DDGS supplement. SEM = pooled standard error of the mean.

One additional factor that could explain the lower than expected DMI and ADG of the calves in the current trial is the NDF content of the forage diets. When NDF is calculated as a percentage of the estimated DMI, the control group (70:30, barley: canola meal) intake was 51.4% NDF, 54.18% NDF for the 70:30 barley: DDGS calves and 59.9% for the 100% DDGS supplemented calves. As explained by Mertens (1987) the NDF content of a forage diet has been shown to influence total dry matter intake (Mertens, 1987). Mertens (1985) demonstrated that NDF intake of an animal should be approximately 1.2% body weight. This equation was later evaluated by Sniffen et al (1992) who concluded that the equation was more accurate when NDF intake was closer to 1.1% of body weight. When comparing the NDF content of the diets provided in the current study as a percentage of BW the groups should have been limited to 5.0 kg/d DMI for the control calves, 4.3 kg/day for the 100% DDGS supplemented calves and 4.7 kg/d for the 70:30 blend supplemented calves. The suggested intake levels determined using the Mertens (1987) equation were similar to the estimated DMI of control barley: canola and 70%:30% barley:DDGS supplemented calves and lower for the estimated intake of the calves supplemented with 100% DDGS. These differences may be explained by the fact that DDGS has a high NDF content. The Mertens (1987) equation was calculated through the assumption that NDF was most highly correlated to the space occupying constituents of the animals diet that relates to rumen fill (Mertens, 1987). Because of the small particle of DDGS the elevated NDF content of the DDGS is not a reflection of the space occupying characteristic as it is with forage. Mertens (1987) equation may not be accurately used for a high NDF, small particle sized supplements like DDGS.

In addition to estimating forage intake using the forage disappearance quadrat method (Jasmer and Holechek 1984), the estimated intake of NE_m (net energy of maintenance) and NE_g (net energy of gain) for calves in this trial were calculated using two different equations (Table 3.4). The first equation developed by Zinn and Shenn (1998) as outlined by McKinnon and Walker (2008) (Appendix equation A3) and estimated NE_m and NE_g based on ADG and estimated DM intake. These calculated NE_m and NE_g values were then compared to the NE_m and NE_g derived from Adams (1995) equation (Appendix Equations A.1 and A.2) which is estimated based on the ADF value of the diets. The comparisons are shown in Table 3.4.

Table 3.4. Theoretical determination of NE_m and NE_g intakes per supplement group

	Zinn and Shen (1998)		Adams (1995)	
Supplement strategy[z]	NE_m[y]	NE_g[x]	NE_m	NE_g
Control (barley:CM blend)	1.53	0.93	1.20	0.64
100% DDGS	1.20	0.64	1.19	0.63
70:30 (barley:DDGS)	1.65	1.03	1.20	0.63

[z]Control = 70:30 barley:canola meal blend; 100% DDGS= dried distillers grains with solubles; 70:30 (barley:DDGS)= 70:30 blend of barley:dried distillers grains.
[y]NE_m = Net energy maintenance
[x]NE_g= Net energy gain

These calculated predicted NEm and NEg may be an indication that the estimated DMI was similar for the 100% DDGS supplemented calves as both equations resulted in similar estimates of NE_m and NE_g for that supplement strategy group. Estimated NE_m and NE_g for the 70:30 blend or control calf groups were not similar between the two equations. If the calculated values using the Zinn and Shen (1998) equation are correct, then it would suggest that more net energy may be available for the calves supplemented with barley grain included in the supplement. If the calculated values using the Zinn and Shen equation are correct, then one would expect animal gains to be lesser for the 100% DDGS supplemented calves due to less energy available, however this was not observed in the current study. Intake was greater for DDGS supplemented calves which could have resulted in the observed better gains attained by the DDGS supplemented claves. Results of the current trial showed that there were no significant (P>0.05) weight differences between supplement treatment groups suggesting that the calculated net energy values using the Zinn and Shen equation were not reflective of the actual energy density of each of the total (forage+supplement) diets. The estimation of NE_m and NE_g using the Adams equation for the three supplement diets seems plausible as the three calculated net energy values resulted in similar estimated NE_m and NE_g (Table 3.4), similar to actual animal performance in the current study where BW did not differ significantly (P=0.44) between the three supplement strategies. The Zinn and Shen (1998) equation for the control calves and the 70:30 calves seems does not reflect the performance data collected suggesting that intake measures influenced the numbers as body weight was similar for the groups. This is because Zinn and Shen's (1998) equation takes into account weight change and estimated intake.

3.3.4 Economic Analysis

The economic analysis calculated for the study was conducted to reflect the cost of a commercial operation backgrounding 200 animals. The Saskatchewan Ministry of Agriculture Farm Machinery Custom and Rental Rate Guide (SMA, 2010) was used to determine labour, equipment, machinery costs, and grazing rates. The DDGS for this trial was obtained through Noramera Bioenergy Corporation (Weyburn, Saskatchewan) and was priced at $155.00 per tonne. The canola meal was priced at $230.00 per tonne and barley was priced at $124 per tonne with an additional $10.00 per tonne added for processing. Barley prices were obtained by averaging prices paid and the prices obtained through CanFax. Limestone, mineral and salt prices were reported as actual costs paid and were priced at $5.49 per 25 kg bag, $32.75 per 25 kg bag, and $5.58 per block, respectively.

Table 3.5 Estimated cost of gain (Fall Grazing trial)

	Control	**DDGS**	**70:30**
		$/head/day	
A. Feed Costs[x]			
CWG pasture	0.25	0.25	0.25
DDGS		0.25	0.12
Canola Meal	0.01		
Rolled barley	0.20		0.11
Mineral and limestone	0.09	0.09	0.09
Total Feed Costs	**0.55**	**0.58**	**0.57**
B. Yardage Costs			
Machinery cost (incl. fuel)	0.06	0.06	0.06
Other labour	0.14	0.14	0.14
Repairs - buildings and corrals	0.01	0.01	0.01
Depreciation	0.01	0.01	0.01
Total Yardage Costs	**0.22**	**0.22**	**0.22**
Total Production Costs (A+B)	**0.77**	**0.80**	**0.79**
Cost of Gain ($/kg)	**1.24**	**1.16**	**1.34**

[z]DDGS= dried distillers grains plus solubles. 70:30 = 70:30% blend of barley:dried distillers grains. CWG pasture= crested wheatgrass pasture.

The difference in total production costs and cost of gain (COG) between the three different supplementation strategies reflects differences in the supplement costs (Table 3.5). Because the three groups of calves were housed and managed similarly in the field site, yardage was the same for each group. Because feed costs contribute to a large proportion of production costs incurred by producers it is essential that feeds costs are taken into account before implementing any stocker feeding and backgrounding program. In the fall of 2009, the price for DDGS was higher than the barley price. For this reason total production cost of feeding 100%

DDGS supplement was higher compared to the other two supplement groups. However, when taking into account the higher gains achieved by the DDGS supplemented calves their total cost of gain ($/kg) was lower than the other supplementation groups.

3.4 Conclusion

This fall grazing trial evaluating 3 supplement strategies demonstrated that calves supplemented with wheat DDGS performed similar to calves supplemented with either a 70:30 blend of barley and canola meal, or a 70:30 blend of barley and dried distillers grains plus solubles. The lack of significant differences in estimated forage intake and performance between supplementation strategies agrees with the hypothesis that calves supplemented with wheat DDGS will perform as well or better than calves supplemented with a barley based supplement in the ration. The economic data revealed that the price of the feed ingredients largely affects the cost of production. The combined animal performance, intake and economic data demonstrates that wheat based DDGS can be used as a reliable supplement in grazing programs when the pasture forage may be deficient in meeting the nutrient (protein or energy) requirements of the animals. The inclusion of DDGS into stocker backgrounding rations will rely on co-product availability and price rather than its effects on animal performance.

4.0 Effects of supplementing wheat-based DDGS to backgrounded stocker calves while winter bale grazing

4.1 Introduction

A typical beef cattle wintering program in western Canada involves feeding preserved forages typically in the form of hay or silage supplemented with a barley grain, most often in a drylot based system. Winter feeding costs are 60 to 68% of the total production cost of a cow-calf operation in western Canada (Kaliel and Kotowich, 2002; Larson, 2010). These increased costs are typically associated with increased nutrient needs of the animal, making of preserved feed, transport of feedstuffs, and costs associated with manure hauling especially in traditional drylot systems (Hitz and Russell, 1998; Volesky et al., 2002). Because of this, any attempt to decrease winter feeding costs will have a greater impact on lowering the overall cost of production for producers. Recent research has demonstrated that extensive based winter management systems can dramatically reduce total wintering costs (Meyer et al., 2009; Kelln et al., 2011; Van De Kerckhove et al., 2011).

One of the most common preserved forage sources to maintain animals through the winter months in western Canada is sun-cured hay in the form of round bales (Saskatchewan Ministry of Agriculture, 2011). Grass-legume hay mixtures are common for reasons associated with nutrient content and forage propagation. Grass hay stands with some alfalfa component are noted for higher protein and energy content for feeding, and nitrogen (N) fixation (Agriculture and Agri-Food Canada, 2013). For the current trial, grass-legume round hay bales were used reflecting a common forage source typically found on farms for winter management of beef cattle in western Canada.

Backgrounding stocker calves in the Canadian winter can result in additional nutritional requirements for the animals. This is because the animals need extra energy and protein due to extreme environmental conditions as well as to meet target gain requirements (National Research Council, 2016). Therefore supplementation of forage based rations when backgrounding beef calves in the winter is essential to get optimal growth (Moore et al. 1999; DelCurto et al. 2000). According to Tarr (2007), Hahn (1999), and Marston et al. (1998) animals experiencing temperatures below -6°C to -8°C would require extra supplemental energy for temperature regulation. Winter in western Canada stays below these suggested temperatures for prolonged periods resulting in additional supplementation.

Typical backgrounding diets in Saskatchewan are comprised of 60-70% forages with the rest of the diet composed of a concentrate source such as barley or other grain types (Klinger 2005; Beauchemin and McGinn 2005). Supplementation is a major contributor to the volatility of feed costs for producers and typically the most expensive addition to a forage based diet. This offers opportunity to producers looking for supplemental feeds for the winter months since wheat based DDGS have been shown through comparison of nutrient content to have optimal energy and protein constituents when compared to other supplements available (Nuez-Ortin, 2010a). Because supplemented wheat based DDGS has not been studied in winter bale grazing programs for beef calves during winter months in western Canada, a 2 yr study was conducted. The specific objectives of the study were; (i) to evaluate the performance of weaned cross-bred beef calves in an extensive winter bale-grazing program supplemented with either wheat DDGS or barley grain; (ii) to estimate daily dry matter (DM) intake and to determine forage displacement due to supplement strategy; and (iii) to conduct an economic analysis of supplementation strategies.

4.2 Materials and Methods

4.2.1 Study Site

A 2-yr winter bale grazing study was conducted at the Western Beef Development Center's (WBDC) Termuende Research Ranch located near Lanigan, Saskatchewan, Canada (51º51'N, 105º02'W). The study site was located on section 27, pasture 14 which was a 5.4-ha dormant grass-legume pasture which was further sub-divided into nine, 0.6-ha paddocks using high tensile electric fence. Over 2 yrs, backgrounding trials were conducted from November 26, 2008 to March 13, 2009 (yr 1, 107 d) and November 27, 2009 to March 14, 2010 (yr 2, 107 d).

4.2.2 Grazing Animal Management

In each year of the trial, the same experimental animals were used for fall, winter, and summer grazing trials, consecutively. Prior to study start, all calves were fed a grass-legume hay based diet for a 21d adaptation period.

Fifty-four (54) cross-bred beef calves (average body weight (BW) = 219.5 ± 8.6 kg) were stratified by BW and randomly allocated to 1 of 3 replicated (n=3) supplement strategies while winter bale grazing; (i) 100% wheat DDGS (DDGS); (ii) 100% barley (CON); or (iii) 50% wheat DDGS + 50% barley (50:50). The ration balancing program (CowBytes Version 4, Alberta Agriculture, Food and Rural Development, Alberta, Canada) was used to determine feed allocation based on BW, forage nutrient analysis, and environmental conditions. The supplementation levels were formulated based on 100 % barley supplementation and then replaced with DDGS at 50% and 100% to make treatment diets. In yr 1, the wheat DDGS was obtained from Husky Energy Ltd. (Lloydminster, Saskatchewan, Canada) while in year 2 the DDGS was a 100% wheat blend received from Noramera Bioenergy Corporation (Weyburn, Saskatchewan, Canada).

Supplement amounts were adjusted throughout the trial to account for increasing nutrient requirements of the stocker cattle due to BW change and temperature fluctuations. Water was delivered daily to water troughs, and straw bedding and one portable wind break (10 × 6 m) per paddock was provided for shelter to each replicate group of calves.

4.2.3 Estimation of Forage DMI and Utilization

Three bales per year in each paddock were weighed prior to bale grazing and following grazing in the spring the remaining residue was weighed for each of the bales. The estimation of forage utilization was obtained by the method explained by Volesky et al. (2010) using the following equation:

$$\text{DMI (kg)} = \frac{\text{(kg DM d}^{-1}\text{ allocated - kg DM d}^{-1}\text{ Residual)}}{\text{n}^{-1}\text{/ d}}$$

Where n= number of cows per experimental unit and d= the number of days the bale forage was allocated.

4.2.4 Environmental Data

During the trial, environmental data was obtained from Termuende Research Ranch Benchmark Site meteorological station located 2 km from the study site and from Environment Canada's Climate Data for Esk, Saskatchewan (51°48′N, 104°51′W; www.climate.weatheroffice.ec.gc.ca). All environmental data is reported in Appendix A.

4.2.5 Laboratory Analysis

Composite hay samples were obtained at the start of trial and every 14 d throughout the trial. All hay samples were dried immediately after collection in a forced air oven for 72 h at 55º Celcius. Prior to analysis all hay and supplement samples were ground to pass through a 1-mm screen using a Wiley mill Tomas-Wiley Laboratory Mill Model 4; Thomas Scientific, Swedesboro, NJ, USA). Duplicate samples were analysed for moisture, crude protein, acid detergent fiber (ADF), neutral detergent fiber (NDF), organic matter (OM), in-vitro organic matter digestibility (IVOMD), calcium (Ca) and phosphorus (P). Digestible energy (DE) of the feed ingredients was calculated based on the Penn-State grass-legume equation for forages (Appendix Equation A1) and the Penn-State cereal grain equation for the supplements (Appendix Equation A2).

Determination of moisture and ash for all samples were analysed using the method outlined by the Association of Official Analytical Chemists (AOAC 2000) (method 930.15). Crude protein (N X 6.25) was analyzed using the Kjeldahl procedure (method 984.12; AOAC 2000) using the 2400 Kjeltic Analyzer unit (Foss Tecator, Hoganas, Sweden). Neutral detergent fiber was analyzed using the ANKOM^{TM}200 fiber analyzer (ANKOM Technology, Fairport, NY). Sulfuric acid and heat were used to analyze ADF (method 973.18; AOAC 2000). Organic matter digestibility was determined using the modified Tilly and Terry (1963) method developed by Goering and Van Soest (1970). Calcium and P were analyzed using the method described by Qian et al. (1994) (method 927.02 and 965.17; AOAC 2000).

Chemical composition of the forage and supplements used in the trial are presented in Table 4.1.

Table 4.1 Chemical composition of hay and supplements in bale grazing trial over 2 yr

	Nutrient Content (%DM)[z]							
Item[y]	DM (%)	CP	ADF	NDF	OM	OMD	Ca	P
Overall Average								
Average	86.8	7.1	44.6	67.3	95.0	45.3	0.57	0.09
Minimum		5.9	38.8	62.2	93.5	39.1	0.49	0.07
Maximum		10.0	52.2	76.4	96.4	49.7	0.71	0.12
SD		1.0	4.4	4.7	0.6	3.6	0.06	0.02
n		18	18	18	18	18	18	18
Year 1 Bale Average								
Average	86.4	7.6	47.4	70.6	95.2	42.9	0.57	0.10
Maximum		10.0	52.2	76.4	96.4	48.7	0.71	0.12
Minimum		5.9	40.4	62.2	93.5	45.8	0.52	0.07
SD		1.2	4.7	4.5	0.6	3.5	0.08	0.02
n		9	9	9	9	9	9	9
Year 2 Bale Average								
Average	87.2	6.5	41.8	64.0	94.7	47.8	0.56	0.08
Maximum		7.0	43.1	65.5	95.4	49.7	0.63	0.08
Minimum		5.9	40.4	62.2	93.5	45.8	0.52	0.07
SD		0.3	0.8	1.1	0.6	1.4	0.04	0.01
n		9	9	9	9	9	9	9
DDGS								
Average	87.5	36.6	16.9	44.7	95.5	69.2	0.10	0.79
Barley								
Average	88.0	15.1	8.0	27.8	97.4	80.6	0.06	0.41

[z]DM= percent dry matter; CP= crude protein; ADF= acid detergent fibre; NDF= neutral detergent fiber; OM=organic matter; OMD= organic matter digestibility; Ca= calcium; P=phosphorus.
[y] SD= standard deviation; DDGS= dried distillers grains with solubles.

Throughout the duration of the trial, all calves were supplemented an average of 3.0 kg (DM) per head per day or 1.1% of BW per head per day. All supplements were fed daily in the morning between 08:30 and 09:30 h and top-dressed with 56 g per calf per day of a 2:1 mineral 20% Ca, 60 ppm Se, 70 ppm Co, 200 ppm I, 3000 ppm Cu, 9000 ppm Mn, 10,000 ppm Zn, 3700 ppm Fe, 1000 ppm F, 1 000 000 IU/kg Vitamin A, 150 000 IU/kg Vitamin D, 1000 IU/kg

Vitamin E: FeedRite Ltd., Humboldt, Saskatchewan, Canada) and 56g per calf per day of limestone (calcium carbonate, 38.0% Ca; FeedRite Ltd., Humboldt, Saskatchewan, Canada). Overall average bale weight was 684.31kgs.

Calf performance measures included BW determined over 2 consecutive d at the start and end of the trial prior to morning feeding and every 14 d during the trial to determine average daily gain. Calf forage intake was estimated using the forage utilization method developed by Volesky et al. (2010) using the following equation:

$$\text{DMI (kg)} = \frac{(\text{kg DM } p^{-1} \text{ allocated} - \text{kg DM } p^{-1} \text{ residual})}{n^{-1}/p}$$

Where p = the number of days per graze period and n = the number of cows per experimental unit.

4.2.6 Statistical Analysis

Statistical analysis for the trial was conducted using the Proc Mixed model procedure of SAS Version 3 (SAS Institute Inc., Cary, NC USA 2005). Data were analysed as a randomized complete block design (RCBD) with calf body weight parameters, ADG and intake estimations analysed as fixed effects with year analysed as a random block effect. All differences were considered significant when $P<0.05$ and all means were separated using Tukey's multi treatment comparison (Saxton, 1998). The experimental model used was:

$$Y_{ij} = \mu + \rho_i + \alpha_j + e_{ij}$$

Where μ is the overall mean of the treatment, ρ_i is the random (block) effect of the *ith* year, α_j is the fixed effect of the *j*th treatment, and e_{ij} is the error term specific to the experimental unit. The assumptions with this analysis is that for all observations the populations are normally, identically, and independently, distributed with equal variability within treatments.

4.3 Results and Discussion

4.3.1 Forage Quality

Chemical composition of the forage and supplements used in this trial are presented in Table 4.1. Grass legume hay fed in yr 1 had a higher CP (7.6%) content compared to yr 2 (6.5%) with an average CP content of 7.1% (DM basis). The hay fed in yr 2 had numerically greater OMD (47.8%) compared to yr 1 (42.9%) hay. The difference in OMD may be attributed to the fact that the ADF and NDF content of the hay used in yr 1 was greater compared to yr 2 hay. This is further supported by the TDN level of the hay, calculated using Penn State equation. For yr 1 the TDN was 48.1%, compared to 54.1% for yr 2 and an overall average of 51.0%. As such, the forage quality alone was not adequate to meet the energy or protein requirements of the yearlings over the winter (NRC, 1996). Therefore, throughout the winter feeding period, additional protein and energy supplementation was supplied as either barley or DDGS or a 50:50 blend. The DM nutrient composition of the DDGS had a CP of 36.6%, ADF 16.9% and NDF 44.7% (DM basis). Barley grain had a CP content of 15.1%, ADF of 8.0% and NDF of 27.8%. The OMD of the 2 supplements was 69.2% for DDGS and 80.6% for barley. Barley TDN was calculated to be 82.6%, while DDGS TDN content was 76.2%. The calculated nutrient composition of the supplements fed along with the hay forage met the requirements of 9.8% CP, and 60% TDN, for 250 kg steers and heifers growing a targeted 0.8 kg/hd d^{-1} and therefore met the needs of the growing yearling animals over the trial period.

4.3.2 Estimated Forage and Total Diet Intake

The effect of supplementation on forage DM intake in winter management systems have been reported to be variable (Rittenhouse et al. 1970). Because low quality forage intake has been shown to increase with protein supplementation (Siebert and Hunter 1982; DelCurto et al. 1990b), our assumption was to expect a higher forage DM intake of the DDGS supplemented calves because of the higher total CP content of their diet. However, this was not the case as the estimated DM intake of hay did not differ (P > 0.05) between supplementation groups (Table 4.2) (P = 0.95), (5.5-5.9 kg/hd/d). This is in contrast to other supplementation studies (Koster et al. 1996; DelCurto et al. 1999; Mathis et al. 1999; Bandyk et al. 2001). Bandyk et al. (2001) infused protein in the form of sodium caseinate both ruminally and postruminally to determine the effects on low quality forage. The authors reported that both locations of protein infusion resulted in greater organic matter intake (OMI) compared to the control animals with no protein infusion. The rumen infusion resulted in a significant increase in OMI compared to the post ruminal infusion treatment. Similarly, Mathis et al. (1999) conducted an experiment looking at increasing supplementation levels 0.08, 0.16, 0.33, and 50% BW of soybean meal (SBM) and its effect on low-quality prairie forage intakes offered *ad libitum*. Results stated that there was a significant cubic effect (P = 0.01) on OMI as the level of supplemented soybean meal increased up to a plateau of 0.16% BW. Both studies demonstrated that protein when limiting can increase low quality forage DM intake.

The lack of response to protein supplementation in the current study as shown in Table 4.2 suggests that protein may not have been a limiting nutrient for calves winter bale grazing. Because of the winter environmental conditions faced by the steers it may be assumed then that energy was the limiting factor affecting forage intake in this trial. This can be explained further by the Mertens (1987) who found that the NDF content of a forage diet has been shown to influence total dry matter intake (Mertens, 1987). Mertens (1985) demonstrated that NDF intake of an animal should be approximately 1.2% body weight. The DDGS supplemented calves were taking in 1.9% of their body weight as NDF.

Moore et al. (1999) concluded that supplementation would increase forage intake if forage intake was less than 1.75% of BW and that the forage TDN to CP ratio was less than 7:1. In the current trial, the forage intake of the animals was calculated to be 1.1% BW and the forage

TDN to CP ratio was 7.2:1. These calculations indicate that supplementation may not have increased forage intake when considering that forage TDN to CP ratio was greater than 7.

Table 4.2 Estimated forage and total intake of calves winter bale grazing

Item	Control	DDGS[x]	50:50[y]	SEM[z]	*P*-value
Estimated intake (kg d^{-1})					
Supplement	3.0	3.0	3.0	-	-
Hay	5.9	5.5	5.7	0.90	0.95
Total diet	8.9	8.5	8.7	1.09	0.95
Estimated intake (% BW d^{-1})					
Supplement	1.1	1.1	1.1	-	-
Hay	2.2	2.1	2.1	0.39	0.95
Total diet	3.2	3.3	3.2	0.49	0.87

[x]DDGS = dried distillers grain plus solubles.
[y]50:50= 50 percent barley and 50 percent DDGS.
[z]SEM = pooled standard error of the mean.

4.3.3 Calf Performance

To date, research studies evaluating winter bale grazing with beef calves in western Canada is limiting. However, in the current study, no differences were detected in calf performance when comparing supplementation strategies while winter bale grazing. There was however, an observed trend (P = 0.07) for ADG and BW change for calves supplemented with DDGS having greater ADG (0.9 kg/d) and BW change (98 kg) compared to control (barley supplemented) calves (0.82 kg/d and 90 kg) as seen in Table 4.3.

The trend of higher ADG observed for the DDGS supplemented calves with no difference in forage intake agrees with the study reported by Rittenhouse et al. (1970). The authors attributed the increased animal gains to the protein supplementation meeting animal requirements at a tissue level rather than stimulating forage digestion. This reasoning can further be supported by the fact that DDGS has been found to have increased bypass protein (Nuez-Ortin, 2010a) making more protein available to meet the animals requirements and less available in the rumen for use by microbes. This may explain the observed trend of increased ADG in the

DDSG supplemented calves compared to the barley supplemented calves. However a more likely reason for increased ADG is the fact that DDGS has a higher energy and CP level compared to Barley.

Table 4.3 Effect of supplementation on calf performance winter bale grazing

Item	Barley	DDGS[x]	50:50[y]	SEM[z]	*P*-Value
Body Weight (kg)					
Initial	218.9	219.2	220.3	7.73	0.79
Final	308.6	317.4	316.2	7.28	0.10
Change	89.7	98.17	95.8	2.44	0.07
Average daily gain (kg d^{-1})	0.82	0.90	0.89	0.02	0.07

[x]DDGS = dried distillers grain plus solubles.
[y]50:50= 50 percent barley and 50 percent DDGS.
[z]SEM = pooled standard error of the mean.

All study diets were formulated to meet the requirements of growing backgrounded calves for a targeted gain of 0.82 kg per day. The barley supplemented calves ADG met the targeted gain, however, the calves supplemented with 100% DDGS or the 50:50 barley-DDGS blend demonstrated a trend to higher average daily gains (Table 4.3). This suggests that the calves supplemented with DDGS in their diet may have received more energy in addition to the increased protein. The estimated forage (hay) intake demonstrated that the calves that had increased ADG did not receive additional energy from the forage as the DMI for the DDGS supplemented calves was the lowest at 5.5 kg per day. This also suggests that most likely, extra energy was coming from the supplemented DDGS which is supported by other studies that demonstrated significantly ($P < 0.05$) increased animal gain and decreased animal days on feed from DDGS replacing barley in feedlot rations (Walter et al. 2010a; McKinnon and Walker 2008).

In addition to estimating forage DM intake using the forage disappearance method (Jasmer and Holechek 1984), the estimated intake of NE_m (net energy of maintenance) and NE_g

(net energy of gain) for calves in the current trial were calculated using two different equations (Table 4.4). The first equation developed by Zinn and Shenn (1998) as outlined by McKinnon and Walker (2008) (Appendix Equation A.3) was used to estimate NE_m and NE_g based on ADG and estimated DM intake. These calculated NE_m and NE_g values were then compared to NE_m and NE_g derived from the Adams (1995) equation (Appendix Equation A.5) where values were estimated based on the ADF content of the study diets. These comparisons are shown in Table 4.4.

Table 4.4. Determination of total NE_m and NE_g intakes per supplement group

	Zinn and Shen (1998)		Adams (1995)	
Supplement strategy[z]	NE_m[y]	NE_g[x]	NE_m	NE_g
Control (barley)	1.01	0.59	1.23	0.66
100% DDGS	1.17	0.62	1.22	0.65
50:50 (barley:DDGS)	1.17	0.62	1.20	0.64

[z]Control = 70:30 barley:canola meal blend; 100% DDGS= dried distillers grains with solubles; 70:30 (barley:DDGS)= 70:30 blend of barley:dried distillers grains.
[y]NE_m = Net energy maintenance
[x]NE_g= Net energy gain

These calculated predictions of NE_m and NE_g suggest that energy supplied by the diets in the current trial where adequate in supplying net energy requirements. This could account for the lack of significant differences in animal performance and estimated intake between the three supplement strategies. It is interesting to note that the Adams (1995) equation determination of energy resulted in a higher predicted NE content of the diets compared to the Zinn and Shen (1998) equation determination. The Adams equation energy predictions suggest that all supplementation groups would have had similar energy diet density compared to the others. This is in contrast to the Zinn and Shen equation energy predictions which suggest that the animals supplemented with DDGS had greater diet energy when compared to the other supplement strategies. This is because the animals supplemented with 100% DDGS had greater gains with numerically lower intakes when compared to the other groups. The difference in predicted NE_m and NE_g values between the two equations was anticipated as the Adams (1995) equation is a prediction based on feed ADF values while the Zinn and Shen (1998) equation is a prediction based on estimated intake and animal performance. The identified trend of animals in this trial having better ADG when supplemented with DDGS is supported the NE predictions of Zinn and Shen shown in Table 4.4.

4.3.4 Economic Analysis

The economic analysis conducted on the winter bale grazing supplement trial was conducted in a way that would accurately reflect costs for a commercial producer whose operation was set up for a herd of approximately 200 animals. Therefore, the Saskatchewan Ministry of Agriculture Farm Machinery Custom and Rental Rate Guide (Saskatchewan Ministry of Agriculture (SMA, 2010) was used to determine labour, equipment and machinery costs, and grazing rates that took into account upkeep and depreciation. In yr 1 of this study, DDGS was obtained through Noramera Bioenergy Corporation (Weyburn, Saskatchewan) and was priced at $155 per tonne. Year two DDGS was obtained through Cargill in Lloydminster and was priced at $147 per tonne. The canola meal cost was $230 per tonne. Barley prices for both yr 1 and yr 2 were obtained by averaging prices paid and with average prices obtained through CanFax. Limestone, mineral and salt block prices were reported as actual costs paid, at $5.49 per 25 kg, $32.75 per 25 kg, and $5.58 per block, respectively.

Table 4.4. Cost analysis of supplementation strategies (Bale Grazing)

	Control		100% DDGS[z]		50:50	
	2008/2009	**2009/2010**	**2008/2009**	**2009/2010**	**2008/2009**	**2009/2010**
A. Feed Costs			*$/head/day*			
Hay	0.80	0.60	0.80	0.63	0.71	0.66
DDGS			0.57	0.43	0.29	0.21
Rolled Barley	0.63	0.38			0.31	0.19
Mineral & Limestone	0.09	0.09	0.09	0.09	0.09	0.09
Total Feed Costs	**1.51**	**1.07**	**1.46**	**1.15**	**1.40**	**1.15**
B. Yardage Costs						
Machinery Cost (incl. fuel)	0.08	0.08	0.08	0.08	0.08	0.08
Labour	0.14	0.14	0.14	0.14	0.14	0.14
Repairs -Portable windbreaks & fence	0.01	0.01	0.01	0.01	0.01	0.01
Depreciation	0.01	0.01	0.01	0.01	0.01	0.01
Total Yardage Costs	**0.23**	**0.23**	**0.23**	**0.23**	**0.23**	**0.23**
Total Production Costs (A+B)	**1.75**	**1.31**	**1.69**	**1.38**	**1.63**	**1.38**
Cost of Gain ($/kg)	**2.05**	**1.65**	**1.90**	**1.52**	**1.85**	**1.59**

[z]DDGS= dried distillers grains plus solubles. 50:50 = 50:50% blend of barley:dried distillers grains.

The economic analysis of this trial demonstrated that production costs varied from yr to yr based solely on changes in feed costs. In yr 1 of the trial, the 50:50 supplemented calves had the lowest cost of production due to the lowest estimated forage DMI for this supplemented group. Comparing supplementation costs in yr 1, the DDGS treatment was the lowest cost strategy to implement. However, in yr 2 the cost of production was lowest for the 100% barley supplemented calves, which can be attributed to the lowest forage DMI for this group and the lower cost of the barley supplement compared to the DDGS and 50:50 blend supplement costs (Table 4.4). The calculated cost of gain for year 1 indicated the 50:50 supplemented calves had the lowest cost gain compared to the other groups, while in yr 2, the DDGS supplemented calves had the lowest cost of gain. This can be attributed to the better ADG observed for the DDGS supplemented group of calves in yr 2 of the study. The cost of gain reported by Larson (2010) is higher than the year 2 cost of gain amounts for the current trial. This makes sense as the current trial used extensive grazing systems which would explain the lower costs attained in the current trial. The prices reported by Larson (2010) compare to year 2 numbers in the current trial as prices for both were obtained the same year.

4.4 Conclusion

In this trial, it was demonstrated that wheat DDGS can be a comparable supplement to barley grain for backgrounding calves. The lack of significant differences in estimated forage DM intake and performance between supplementation strategies supports the theory that calves supplemented with wheat DDGS will perform as well or better than calves supplemented with barley grain in the ration. The economic analysis revealed that the price of the feed ingredients largely affects total cost of production. The combined animal performance, intake and economic data further demonstrates that wheat based DDGS can be used as a reliable supplement in winter grazing programs when pasture forage may be deficient in meeting protein or energy nutrient requirements of the animals. The inclusion of DDGS into stocker backgrounding rations will rely on the co-products availability and price rather than any effect on animal performance.

5.0 Effect of supplementing wheat-based DDGS to stocker calves on summer pasture

5.1 Introduction

Although not as common as spring, fall, and winter pasture supplementation summer pasture supplementation is sometimes necessary to attain desired gains. Sewell (1993) explains the reasons for pasture supplementation as 1) to lower feed costs of calf gains; 2) to increase the number of stocker cattle grazed per acre; 3) to decrease the weight at which large frame cattle have choice grade carcasses; 4) to hasten the marketing date of grazed cattle that are to be finished for slaughter; 5) to supplement pasture during drought or seasons of low production. The most common of these reasons is hasten marketing dates or to supplement pasture that falls short of meeting the animals requirements.

Supplementation costs reflect a good proportion of variable costs that are associated with beef production (Stalker 2009). This is due to the volatile nature of feed grain markets and the fact that stocker calves are traditionally supplemented with cereal grains in the ration. With the expansion of the ethanol industry and increased availability of DDGS, the DDGS has been proven as a comparable supplement for beef cows (Neuz-Ortin and Yu 2010; Van De Kerckhove 2011). There may also be an opportunity for beef producers to look at alternate supplementation strategies for backgrounding calves. As barley grain is typically used in western Canadian diets any research that compares DDGS as a supplement needs to include barley. The specific objectives of this research were to evaluate the performance of weaned cross-bred beef calves in an extended fall grazing program supplemented with either wheat DDGS or barley grain, to estimate DMI and to determine forage displacement due to supplementation strategy and to conduct an economic analysis for each supplementation strategy

5.2 Materials and Methods

5.2.1 Study Site

A two year fall grazing study was conducted at the Western Beef Development Center's Termuende Research Ranch located near Lanigan, Saskatchewan, Canada (51º51'N, 105º02'W). The trial took place on section 27, pasture 12. Eighteen ha of crested wheatgrass (*Agropyron cristatum L.)* were divided into 9, 2 ha paddocks as shown in Appendix Table A1. On May 26th, 2009, the first trial started, and lasted for 32 days until June 26th, 2009. In year 2, the summer grazing study was managed from May 26th, 2010 to July 10th, 2010 for 42 days.

5.2.2 Grazing Animal Management

In each year of the trial, the same experimental animals were used for fall, winter, and summer grazing trials consecutively. Prior to study start, all calves were fed a grass-legume hay based diet for a 21d adaptation period.

After being weighed for two consecutive days prior to allocating daily supplement the 54 cross-bred beef calves (2 year average body weight (BW) = 342.8 ± 12.2 kg) were stratified by BW and randomly allocated to 1 of 3 replicated (n=3) supplement strategies while summer grazing; (i) 100% wheat DDGS (DDGS); (ii) 100% barley (CON); or (iii) 50% wheat DDGS + 50% barley (50:50). The ration balancing program (CowBytes Version 4, Alberta Agriculture, Food and Rural Development, Alberta, Canada) based on NRC (2000) was used to determine feed allocation based on BW, forage nutrient analysis, and environmental conditions. Diets were formulated using barley as the supplement and then barley was replaced at 50% and 100% to make up the other experimental diets. In yr 1, the wheat DDGS was obtained from Husky Energy Ltd. (Lloydminster, Saskatchewan, Canada) while in year 2, the DDGS was a 100% wheat blend from Noramera Bioenergy Corporation (Weyburn, Saskatchewan, Canada).

Throughout the duration of this trial calves received an average of 1.3 kg (DM) of supplement per head per day or 0.4% of BW per head per day to gain a desired 0.82kg/day. All supplements were fed daily in the morning between 0830 and 0930, top dressed with 56g per calf per day of 2:1 mineral (20% Ca, 60 ppm Se, 70 ppm Co, 200 ppm I, 3000 ppm Cu, 9000 ppm Mn, 10,000 ppm Zn, 3700 ppm Fe, 1000 ppm F, 1 000 000 IU/kg Vitamin A, 150 000 IU/kg Vitamin D, 1000 IU/kg Vitamin E: FeedRite Ltd., Humboldt, Saskatchewan, Canada) and 56g per calf per day of limestone (calcium carbonate, 38.0% Ca; FeedRite Ltd., Humboldt, Saskatchewan, Canada).

Calf performance measures included BW gain and feed intake. Calf BW was measured on 2 consecutive days of the start and end of trial prior to morning feeding, and every 14 d during the trial. Calf feed intake was estimated using the herbage disappearance method described by Jasmer and Holenchek (1984).

5.2.3 Forage Utilization Estimate

The estimation of forage utilization was done using the herbage disappearance method described by Jasmer and Holechek (1984). A $0.25m^2$ quadrat was used and randomly placed in the paddock to be sampled. Once placed the forage within the quadrat was clipped to a 4cm stubble height. Each quadrat sample taken was dried separately at 55ºC for 72 hours and weighed. 30 of these samples were taken randomly in each of the nine paddocks at the beginning middle and end of the trial. After all samples were dried and weighed, the difference of the beginning weights compared to the end weights was considered herbage disappearance and was extrapolated to the herbage disappearance for the whole pasture (g per $0.25m^2$ to kg per ha). Finally an estimation of forage DMI was calculated. Calculations were done using the following equations:

$$\% \text{ Herbage Disappearance} = \frac{(\text{g DM per } 0.25\text{m}^2 \text{ available} - \text{g DM per } 0.25\text{m}^2 \text{ residual})}{(\text{g DM per } 0.25\text{m}^2 \text{ available})}$$

$$\text{DMI (kg)} = \frac{(\text{kg DM d}^{-1} \text{ allocated - kg DM d}^{-1} \text{ Residual})}{\text{n}^{-1}/\text{ d}}$$

Where n= number of cows per experimental unit and d= the number of days that the paddock was grazed.

5.2.4 Environmental Analysis

For the duration of the trial environmental data was received from Termuende Research Ranch Benchmark Site meteorological station located on section 35 at the Western Beef Development Center. Daily minimum and maximum temperatures along with precipitation were recorded for this trial at this site. For records unattainable at this site records were received from Environment Canada's Climate Data Online (www.climate.weatheroffice.ec.gc.ca) for Esk, Saskatchewan, approximately 5-6 km southeast of the study site (51°48 'N, 104°51 'W).

5.2.5 Laboratory Analysis

All pasture clips were dried immediately after collection in a forced air oven for 72h at 55ºC. Prior to analysis all forage and supplement samples were ground through a 1-mm screen (Tomas-Wiley Laboratory Mill Model 4; Thomas Scientific, Swedesboro, NJ, USA). All samples were analysed for moisture, crude protein, acid detergent fiber, neutral detergent fiber, organic matter, in-vitro organic matter digestibility, calcium and phosphorus. Digestible energy of the feed ingredients was calculated based on the Penn-State grass-legume equation (Appendix

Equation A1) for the forage and the Penn-State cereal grain equation for the supplements (Appendix Equation A2).

Determination of moisture and ash for all samples were analysed using the method outlined by the Association of Official Analytical Chemists (method #930.15 and #942.05; AOAC 2000). Crude protein (nitrogen X 6.25) was analyzed using the Kjeldahl procedure (method #984.12; AOAC 2000) using the 2400 Kjeltic Analyzer unit (Foss Tecator, Hoganas, Sweden). NDF was analyzed using the Ankom fiber analyzer (Ankom Technology, NY). Sulfuric acid and heat was used to analyze ADF (method #973.18; AOAC 1997). OMD was determined using the updated Tilly and Terry (1963) method developed by Goering and Van Soest (1970). Calcium and phosphorus were analyzed using the method described by Qian et al. (1994) (method # 927.02 and # 965.17; AOAC 2000).

5.2.6 Statistical Analysis

Statistical analysis for this trial was done using the proc mixed model procedure if SAS (2005). Data was analysed as a randomized complete block design with calf body weight parameters, ADG and intake estimations analysed as fixed effects with year as the random block effect. All differences were considered significant when P<0.05 and all means were separated using Tukey's multi treatment comparison (Saxton, 1998). The experimental model used was:

$$Y_{ij} = \mu + \rho_i + \alpha_j + e_{ij}$$

Where μ is the overall mean of the treatment, ρ_i is the random (block) effect of the *ith* year, α_j is the fixed effect of the *j*th treatment, and e_{ij} is the error term specific to the experimental unit. The assumption with this analysis is that for all observations the populations are normally, identically, and independently, distributed with equal variability within treatments.

5.3 Results and Discussion

5.3.1 Pasture Quality

Chemical composition of pasture forage at the start and end of each of the two trials are presented in Table 5.1. A comparison of the nutrient composition of the stockpiled crested wheatgrass pasture evaluated at the start and end of the trial suggests that the quality declined over time (Table 5.1). A decrease in CP content and increase in fiber content as the growing season advances is well documented and can be attributed to both senescence and an increase in plant maturity (Wilson 1982; Van Soest 1994; Vallentine 2001) for crested wheatgrass as the season progresses (Bruynooghe 1997; Baron et al. 2004). It has been documented that in semiarid region of western Canada, optimal use and nutritive quality of crested wheatgrass occurs in May and June and thereafter declines with advancing maturity and lower nutritive value and intake (Iwassa et al. 2014). Another factor that may contribute to the suggested quality decline as the season progresses is that animals seek out the more lush grass and eat it first, leaving the less desirable lower quality forages to be left in the paddock as the season progresses (Agriculture Canada 1970; Smoliak et al, 1981).

Table 5.1 Start of trial and end of trial summer pasture nutrient composition

	Nutrient Content (%DM) [z]						
Item	CP	ADF	NDF	OM	OMD	Ca	P
Year 1Average start of trial							
Average	14.4	29.38	57.3	93.1	57.0	0.38	0.14
Maximum	15.9	31.5	59.7	94.0	63.2	0.53	0.17
Minimum	13.3	25.9	53.3	91.4	53.1	0.29	0.10
SD	0.83	1.6	1.74	0.70	2.67	0.07	0.02
n	30	30	30	30	30	30	30
Year 1 Average end of trial							
Average	13.3	32.5	65.0	93.3	51.8	0.36	0.15
Maximum	14.9	34.0	66.4	94.3	54.6	0.41	0.21
Minimum	10.2	30.8	63.4	91.8	47.9	0.30	0.12
SD	1.38	1.01	0.99	0.84	1.93	0.04	0.02
n	30	30	30	30	30	30	30
Year 2 Start of trial							
Average	17.3	27.0	49.5	92.7	60.7	0.44	0.12
Maximum	19.1	29.2	54.8	93.5	64.8	0.51	0.24
Minimum	14.6	24.0	45.6	92.2	58.1	0.35	0.11
SD	1.59	2.22	3.27	0.31	2.05	0.09	0.08
n	30	30	30	30	30	30	30
Year 2 End of trial							
Average	15.6	28.72	51.02	92.41	54.87	0.42	0.19
Maximum	17.82	31.23	55.03	93.48	57.38	0.48	0.23
Minimum	14.55	25.36	48.21	91.16	53.06	0.36	0.23
SD	1.12	2.02	2.45	0.8	1.8	0.038	0.04
n	30	30	30	30	30	30	30

[z]DM= percent dry matter; CP= crude protein; ADF= acid detergent fibre; NDF= neutral detergent fiber; OM=organic matter; OMD= organic matter digestibility; Ca= calcium; P=phosphorus.

The average chemical composition in year 1 and 2 as well as the supplements used are presented in Table 5.1. When the overall average nutrient composition of crested wheatgrass pasture (Table 5.1) is put into the Adams equation (1995) the calculated NEm 1.19 Mcal/kg and the calculated NEg is 0.63 Mcal/kg. According to NRC the NEm and NEg for a 589.7 kg finishing feedlot steer or heifer at a current 353.8 kg, targeted for 0.96 kg (2.11 lb/d) gain would be 1.34 Mcal/kg and 0.77 Mcal/kg consecutively with 9.6% CP total diet. This suggests that the grass alone would be slightly short in energy to meet the needs of these animals to gain the targeted 0.81 kg/day (1.8 lb/d).

Table 5.2 Average nutrient composition of summer CWG Pasture

	Nutrient Content (%DM)[z]							
Item	DM (%)	CP	ADF	NDF	OM	OMD	Ca	P
Overall Average								
Average	66.5	15.2	29.4	55.7	92.9	56.1	0.40	0.16
Maximum	70.3	17.5	32.6	60.7	94.0	63.2	0.52	0.23
Minimum	63.0	12.4	25.0	49.5	91.4	50.5	0.30	0.11
SD	3.66	1.64	2.04	3.37	0.66	3.31	0.06	0.03
n	120	120	120	120	120	120	120	120
Year 1 Average								
Average	65.4	13.9	30.9	61.2	93.2	54.4	0.37	0.15
Maximum	68.1	15.9	34.0	66.4	94.6	61.7	0.53	0.21
Minimum	61.5	10.2	25.9	53.3	91.6	47.9	0.29	0.10
SD	0.02	1.49	1.88	3.46	0.71	3.10	0.05	0.02
n	60	60	60	60	60	60	60	60
Year 2 Average								
Average	67.6	16.5	27.9	50.3	92.6	57.8	0.43	0.16
Maximum	72.4	19.1	31.2	55.0	93.5	64.8	0.51	0.24
Minimum	64.5	14.6	24.0	45.6	91.2	53.1	0.31	0.11
SD	7.3	1.8	2.2	3.3	0.6	3.5	0.06	0.03
n	60	60	60	60	60	60	60	60
DDGS[y]								
Average	87.6	37.9	13.3	50.3	96.0	69.6	0.09	0.73
Barley								
Average	88.0	14.7	7.5	26.5	97.5	81.1	0.05	0.38

[z]DM= percent dry matter; CP= crude protein; ADF= acid detergent fibre; NDF= neutral detergent fiber; OM=organic matter; OMD= organic matter digestibility; Ca= calcium; P=phosphorus.
[y]DDGS= dried distillers grains with solubles.

5.3.2 Forage Utilization and Estimated Intake

Forage utilization and estimated DM intake of summer pasture and supplements are presented in Table 5.3. There was a significant difference ($P<0.05$) in residual forage, consumed forage and utilization between the DDGS supplemented calves and the other 2 groups (Control and 50:50). The effect of protein supplementation has been shown to increase forage DM intake (Pond 2005; Koster et al. 1996; Beaty et al. 1994; Van Soest et al. 1991). Grazing ruminant response to supplemental protein is usually observed when the CP content of the basal diet is less than 6 to 8 % (DelCurto et al. 2000). This was not the case in the current trial as the forage alone supplied an overall average of 15.4% CP (Table 5.1) and the diet with the most supplemented CP was the DDGS group that showed reduced forage intake and utilization. This is in contrast to findings by Poore et al. (2006) who found no difference ($P > 0.20$) in forage utilization for beef heifers grazing stockpiled tall fescue forage with or without supplementation.

Measurement of intake of individual grazing animals remains one of the fundamental challenges to improving efficiency of livestock production (Lukuyu et al., 2014). The estimated total intake of the animals (Table 5.3) as a percentage of BW was 2.3% for the control calves, 1.3% for the DDGS calves and 2.2% for the 50:50 supplemented calves. According to CowBytes Beef Ration Balancing Program (Version 4, Alberta Agriculture, Food and Rural Development) the control diets estimated forage utilization would support 0.69 kg/hd/d of gain while the DDGS diet using the estimated intake would result in a weight gain of 0.41 kg/hd/d using the nutrient composition analysis in Table 5.1 and 5.2. Compared to the actual gains measured these calculations indicate that there were potential deficiencies with the forage disappearance method used in this study to determine forage utilization and intake.

Table 5.3 Estimated utilization and intake of calves on summer pasture

Item	Control	DDGS[x]	50:50	SEM[y]	P-value
Available Forage (kg/ha)	2355.7	2338.3	2356.6	103.54	0.97
Residual Forage (kg/ha)	1814.9	2096.2	1796.1	265.19	0.02
Consumed (kg/ha)	540.8	242.1	560.0	184.38	0.06
Utilization (%)	23.0A	10.3B	23.8A	0.08	0.04
Estimated Intake (kg/hd/day)					
Supplement	1.3	1.3	1.3	N/A	N/A
CWG[z]	5.6	2.4	5.5	2.32	0.06
Total	6.8	3.7	6.8	2.82	0.06
Estimated Intake (%BW/hd/day)					
Supplement	0.4	0.4	0.4	N/A	N/A
CWG	1.9	0.8	1.8	0.91	0.07
Total	2.3	1.3	2.2	1.12	0.07

[x]DDGS = dried distillers grain plus solubles.
[y]SEM = pooled standard error of the mean.
[z]CWG= crested wheatgrass.

5.3.3 Calf Performance

When comparing supplementation strategies fed to calves grazing summer pasture there were no differences (P > 0.05) on calf final BW, BW change or average daily gain (ADG) (Table 5.4).

Table 5.4 Effect of supplementation on calf performance grazing summer pasture

Item[z]	Control	DDGS	50:50	SEM	P-Value
Body Weight					
Initial (kg)	342.17	341.7	342.67	4.22	0.66
Final (kg)	385.21	385.6	385.7	2.48	0.98
Change (kg)	43.1	43.98	43	3.21	0.95
Average Daily Gain (kg/day)	1.16	1.16	1.14	0.16	0.97

[z]DDGS = dried distillers grains plus solubles; 50:50 = 50% barley and 50% DDGS supplement.
SEM = pooled standard error of the mean.

In addition to estimating forage intake using the forage disappearance quadrat method (Jasmer and Holechek 1984) the estimated intake of NE_m (net energy of maintenance) and NE_g

(net energy of gain) for calves in this trial were calculated using the NE_m and NE_g derived from Adams (1995) equation (Appendix Equation A.5) which is estimated based on the ADF value of the diets. The numbers are shown in Table 5.5.

According to NRC (1995) a 590 kg at finishing feedlot steer and heifer at a current 353.8 kg would need 60% TDN, NE_g at 0.77 Mcal/kg, an NE_m of 1.34 Mcal/kg, a DMI of 9.48kg and a CP of 9.6% DM to gain 0.95kg. The Adams prediction equation NE_m and NE_g in Table 5.5 suggests that the animals may have been short of nutrients to gain 0.95kg which is higher than the targeted 0.82kg. This is not supported by the measured BW gain of 1.15 kg/day. Demonstrating that there was more energy in the actual diet then reflected by the Adams prediction equation which uses ADF to predict diet energy.

Table 5.5 Theoretical determination of NE_m and NE_g intakes per supplement group

	Adams (1995)	
Supplement strategy[z]	NE_m	NE_g
Control (barley:CM blend)	1.23	0.66
100% DDGS	1.22	0.66
50:50 (barley:DDGS)	1.24	0.67

[z]Control = 100% barley; 100% DDGS= dried distillers grains with solubles; 50:50 (barley:DDGS)= 50:50 blend of barley:dried distillers grains.
[y]NE_m = Net energy maintenance
[x]NE_g= Net energy gain

The Adams (1995) calculated prediction of NE_m and NEg may be an indication that the actual DMI and BW gain was similar for between all 3 groups. This is supported by the close wight gains shown in Table 5.4. Estimated NE_m and NE_g were not similar between the two equations. The estimation of NE_m and NE_g using the Adams equation for the three supplement diets seems plausible as the three calculated net energy values resulted in similar estimated NE_m and NE_g (Table 5.5), similar to actual animal performance in the current study where BW did not differ significantly (P=0.95) between the three supplement strategies.

5.3.4 Economic Analysis

The economic analysis calculated for the study was conducted to reflect the cost of a commercial operation backgrounding 200 animals. The Saskatchewan Ministry of Agriculture Farm Machinery Custom and Rental Rate Guide (SMA, 2010) was used to determine labour, equipment, machinery costs, and grazing rates. In yr 1 of this study DDGS was obtained through Noramera Bioenergy Corporation (Weyburn, Saskatchewan) and was priced at $155 per tonne. Year two DDGS was obtained through Cargill in Lloydminster and was priced at $147 per tonne. The canola meal cost was $230 per tonne. Barley prices for both yr 1 and yr 2 were obtained by averaging prices paid and average prices obtained through CanFax. Limestone, mineral and salt block prices were reported as actual costs paid, at $5.49 per 25 kg, $32.75 per 25 kg, and $5.58 per block, respectively.

Table 5.6 Cost of gain (Summer Grazing)

	Control		100% DDGS[z]		50:50	
	2009	**2010**	**2009**	**2010**	**2009**	**2010**
A. Feed Costs[y]			*$/head/day*			
CWG Pasture	0.50	0.50	0.50	0.50	0.50	0.50
DDGS			0.33	0.12	0.17	0.06
Rolled Barley	0.36	0.10			0.18	0.05
Mineral & Limestone	0.09	0.09	0.09	0.09	0.09	0.09
Total Feed Costs	**0.95**	**0.69**	**0.92**	**0.71**	**0.93**	**0.70**
B. Yardage Costs						
Machinery Cost (incl. fuel)	0.06	0.06	0.06	0.06	0.06	0.06
Labour	0.14	0.14	0.14	0.14	0.14	0.14
Repairs - Fence	0.01	0.01	0.01	0.01	0.01	0.01
Depreciation	0.01	0.01	0.01	0.01	0.01	0.01
Total Yardage Costs	**0.22**	**0.22**	**0.22**	**0.22**	**0.22**	**0.22**
Total Production Costs (A+B)	**1.17**	**2.25**	**1.14**	**2.54**	**1.15**	**2.40**
Cost of Gain ($/kg)	**0.83**	**0.88**	**0.90**	**0.79**	**0.90**	**0.84**

[z]DDGS= dried distillers grains plus solubles. 50:50 = 50:50% blend of barley:dried distillers grains.
[y]CWG pasture= crested wheatgrass pasture.

The economic analysis of this trial demonstrated that production costs varied from yr to yr based solely on changes in feed costs. In yr 1 of the trial, the 100% DDGS supplemented calves had the lowest cost of production at $1.14 compared to $1.15 for control calves. However, in yr 2 the cost of production was lowest for the control calves at $2.25 compared to $2.54 for DDGS calves. Pasture grazing costs remained the same between years of the trial and between groups. This means that changes in cost of production are solely an indication of the difference in supplement cost.

Cost of production is the total production costs of an animal divided by days that animal is in the calculated production stage. Whereas cost of gain is the cost of production divided by the weight in wither kg or lbs. The calculated cost of gain for year 1 indicated the 100% control calves had the lowest cost gain compared to the other groups, while in yr 2, the 100% DDGS supplemented calves had the lowest cost of gain. This can be attributed to the better ADG observed for the 100% Barley supplemented group of calves in yr 1 and the better ADG of 100% DDGS supplemented calves in yr 2. The cost of gain of the groups in this study are in contrast to Larson (2010) who found cost to be $0.88.lb of weaned calf in a cost of production analysis. This can be explained by the lack of dry lot needed in this study which is associated with higher costs of gain and production (Larson, 2010; Kaliel and Kotowich, 2002; Larson, 2010).

5.4 Conclusion

This summer grazing trial evaluating 3 supplement strategies demonstrated that calves supplemented with wheat DDGS performed similar to calves supplemented with either a 50:50 blend of barley and DDGS, or 100% barley. The lack of significant differences in performance between supplementation strategies agrees with the hypothesis that calves supplemented with wheat DDGS will perform as well or better than calves supplemented with barley based supplements in the ration. The significant difference ($p<0.05$) of the forage utilization estimate compared to the gains observed and the estimated energy supplied in the diet indicate that there may have been deficiencies in the herbage disappearance method used. The economic data revealed that the price of the feed ingredients largely affects the cost of production. The combined animal performance, intake and economic data demonstrates that wheat based DDGS can be used as a reliable supplement in summer grazing programs when the pasture forage may be deficient in meeting the nutrient (protein or energy) requirements of the animals. The inclusion of DDGS into stocker backgrounding rations will rely on the co-product availability and price rather than its effects on animal performance.

6.0 Using Sheep as a Model to Determine the Effect of Wheat- Based DDDS on Apparent Digestibility, Voluntary Intake, and Ingredient Digestibility

6.1 Introduction

Ethanol production has increased in Canada. Increases in ethanol production are strongly influenced by provincial and federal policies. A mandate set by the Canadian Government requires unleaded fuel to contain 5% ethanol (Canadian Renewable Fuels Association, 2010). The expansion of the ethanol industry in western Canada has led to increased amounts of wheat dried distillers grains with solubles (DDGS) as a co-product which is available for use in animal rations. In Saskatchewan 4 ethanol plants exist and are responsible for producing approximately 320 million litres of ethanol along with 339,000 metric tonnes of wheat dried distillers grains (www.ddgs.usask.ca). When wheat is used for ethanol production, the starch is digested via fermentation, leaving the resulting co-products with approximately three times the concentration of the other nutrients when compared to the initial grain used (Mustafa et al.2000). This increase in nutrients may make DDGS a comparable supplement to barley in ruminant rations; however DDGS is high in crude protein (CP) and phosphorus (P) which may lead to environmental implications when excreted by the animals (Walker, 2003). As well, DDGS has elevated sulphur content. When feeding DDGS to ruminants it is essential to make sure that their sulphur intake remains below 0.4% of the total diet to eliminate the risk of polioencephalomalacia (Walker, 2003; NRC, 2001).

Efforts to reduce feeding costs in western Canada, has led to an increase in low quality forages in ruminant diets (Krause et al. 2013; Kelln et al., 2011; Van De Kerckhove et al., 2011). Supplementation is often necessary to meet the requirements of growing ruminants that are fed a diet of low quality forages (NRC, 2001). DDGS has the potential to meet the requirements of growing animals through its high protein content, highly digestible fibre, and elevated fat content

(Schingoethe, 2006). Protein supplements have been shown to promote fibre digestion by providing the nitrogen needed to support a healthy rumen microbe population (Mathis et al. 1999).

In October, 2008, a study was initiated at Western Beef Development Center in Lanigan SK to compare the supplementation of wheat DDGS alone or in combination with barley grain to calves grazing crested wheatgrass pasture in Summer and Fall, and while winter bale grazing. Ruminant grazing trials are an extremely important tool for the research community, producers, and extension workers. Field grazing trials pose unique obstacles typically associated with methods available for data collection such as estimation of intake and digestibility (Lipke 2002). Even though many methods have been researched for estimating intake on pasture, these techniques can be associated with errors when compared to a metabolic digestibility trial. Another issue for grazing trial research is accurately determining the digestibility of the diet consumed. Therefore the specific objectives of this study was to use ram lambs as a model for calves to evaluate the effect of 3 supplements fed in a forage based diet on voluntary intake and apparent nutrient digestibility.

6.2 Materials and Methods

6.2.1 Animals, Housing and Experimental Design

Twenty four June born Suffolk ram lambs weighing initially an average of 43.5 ± 5 kg were used for the trial. The animals were weighed and randomly allocated to one of the 3 diets (8 animals per treatment). Growing ram lambs were used to extrapolate data to the growing yearling steers used in the field grazing studies. Lambs have been successfully used in digestibility trials as a model for cattle digestion (Lardner et al. 2002; Troelsen, 1966). Throughout the duration of the trial, lambs were housed in individual metabolism crates at the

Livestock Research Building (University of Saskatchewan). Animals were fed diets twice a day along with available water *ad libitum*. All diets were top dressed with 10g of mineral and limestone daily. Animals were cared for and handled in accordance with guidelines of the Canadian Council on Animal Care (2009).

The experiment was 21 d long and consisted of a 7-d dietary adaptation period, a 7-d voluntary intake period, a 3-d restricted intake period followed by a 5 d collection period. Lambs were adjusted to the barn environment and basal forage diet during the adaptation period while during the voluntary intake period, the basal forage was provided in order to measure the total amount that the lambs would consume voluntarily (fed to leave 10-15% orts). Lambs were then restricted for 3 d before the collection period to ensure all of the diet was consumed during the 5 d collection phase (85% of *ad libitum* feed intake). Through the duration of the trial, lambs were housed at the Livestock Research Building (University of Saskatchewan) in a temperature controlled environment (18 to 22°C).

6.2.2 Treatment and Dietary Compositions

Three diets were formulated using 3 supplementation strategies (treatments). The supplements were fed at 50% of the total diet with the other 50% of the diet consisting of crested wheatgrass hay. The supplement strategies used were (1) 100% rolled barley grain (Control); (2) 100% wheat-corn blend DDGS (DDGS); (2); or 50% blend DDGS and 50% rolled barley grain (50:50).

Experimental diets were fed twice daily as chopped hay top dressed with supplement. The hay used in the trial contained 91.61% DM with a chemical composition on a DM basis at 54.2% OMD, 7.2 % CP, 72.4 % NDF, 0.3% Ca and 0.2% phosphorous.

6.2.3 Data Collection

Following the 7-d dietary adjustment period, voluntary intake was determined over 7 d by weighing all feed and orts. Once voluntary intake was determined, lambs were restricted to 85% of *ad libitum* intake for 3-d followed by a 5-d collection phase where feces and orts were collected 2 times daily. During the collection period, total feces were recorded daily and a representative sample (10%) was taken and dried immediately for 72 h at 55ºC in a forced air oven. Feces were collected using a collection bag attached by a harness to the rear of each lamb. After drying, all feces were ground and used for proximate analysis to determine diet digestibility. All diet ingredients were sampled weekly and were analysed using proximate analysis. Feces and feed were ground through a Christie-Norris mill fitted with a 1 mm screen.

6.2.4 Laboratory Analysis

All dried diet samples and fecal subsamples were ground to pass through a 1-mm screen using a Christy- Norris mill (Christy Norris LTD, Chelmsford, UK). The ground samples were then pooled for each lamb and then duplicate samples were analyzed for organic matter (OM) by ashing at 600ºC for at least 8 h (AOAC, 2000; method 942.05).Crude protein (CP) was analyzed using the macro-Kjeldahl procedure (AOAC, 1990; method 990.03), ether extract was analyzed (AOAC, 1990; method 920.39). Acid-detergent fiber (ADF; AOAC, 1990), and neutral detergent fiber (NDF) were analyzed by following Van Soest et al. (1991). Digestible energy (DE) of the feed ingredients was calculated based on the Penn-State grass-legume equation for forages (Appendix Equation A1) and the Penn-State cereal grain equation for the supplements (Appendix Equation A2).Organic matter digestibility was determined using the updated Tilly and Terry

(1963) method developed by Goering and Van Soest (1970). Dry matter digestibility (DM) was determined using the following equation:

$$\text{Dry matter digestibility (\%)} = \frac{\text{DM in feed} - \text{DM in Feces}}{\text{DM in Feed}}$$

Individual nutrient digestibility was determined by conducting proximate analysis on the pooled feed and fecal samples using the methods listed above and determined using the following equation:

$$\text{Nutrient digestibility} = \frac{(\text{DM intake} * \text{nutrient in feed}) - (\text{DM feces} * \text{nutrient in Feces})}{(\text{DM intake} * \text{nutrient in feed})}$$

6.2.5 Statistical Analysis

The experimental design of the digestibility trial was a completely randomized design with 24 animals allocated to 1 of the 3 supplementation strategies. For the diet digestibility study, intake (DMI) and total tract digestibility data (OMD and DMD) were analyzed using the Proc Mixed Model procedure of SAS (2003). Each lamb was considered an experimental unit (8 animal each treatment). The model used for the analysis was: $Y_{ij} = \mu + T_i + e_{ij}$; where Y_{ij} was an observation of the dependent variable ij; μ was the population mean for the variable; T_i was the fixed effect of diet treatment (Control, DDGS, and 50:50); and e_{ij} was the random error associated with the observation ij. Means were determined using the least squares means statement of SAS and were separated using Tukey's multi-treatment comparison method (Saxton, 1998). For all statistical analyses, significance was declared at $P < 0.05$.

6.3 Results and Discussion

6.3.1 Voluntary Dry Matter Intake

Dry matter intake data from the sheep trial given in Table 6.1 indicates that there was no significant ($P>0.05$) effect of supplement strategy on DM intake. Numerically, voluntary intake was highest in the DDGS fed calves, and lowest in the control calves. A lack of significant difference in DM intake for sheep supplemented with DDGS has been reported by other studies (Powers et al., 1995; Liu et al., 2000; Anderson et al., 2006; et al.; Kleinschmit et al. 2006; Van Emon et al., 2012). Abdelrahim et al. (2014) hypothesized that increasing levels of DDGS in lamb rations would not affect lamb DM intake. The hypothesis was correct when the authors compared levels of 0, 17 and 25.4% of the diet as dried distillers grains plus solubles. Other studies have reported contrasting findings where increasing levels of DDGS in the diet increased DMI of the total diet (Archibeque et al. 2008; Schauer et al. 2008). Schauer et al. (2008) replaced 0, 20, 40, and 60% of the barley in finishing lamb diets with supplemented DDGS and found that DMI increased in a linear manner as DDGS inclusion in the diets increased.

Table 6.1 Effect of supplementation strategy on intake and apparent digestibility from sheep digestibility trial

	TRT[z]				
Item[y]	DDGS	Control	50:50	SEM	*P* value
Intake Parameters					
BW (kg)	44.9	42.5	43.1	1.18	0.35
Forage intake (kg d^{-1})	0.55	0.51	0.53	1.18	0.35
Voluntary Intake (kg d^{-1})	1.10	1.01	1.05	0.05	0.41
DM intake (% of BW)	2.46	2.39	2.45	0.10	0.87
Apparent total tract digestibility (%)					
CP	76.6^{A}	66.7^{B}	67.5^{B}	0.33	0.01
ADF	67.4^{A}	62.8^{B}	63.2^{AB}	0.42	0.02
GE	69.8	70.2	68.7	1.12	0.38
OMD	70.6	70.8	70.2	0.92	0.90
DMD	69.9	67.5	68.4	1.52	0.63

[z]DDGS= dried distillers grains with solubles; 50:50= 50% barley:50% DDGS; SEM – pooled standard error of the mean

[y]BW= body weight; DMI = dry matter intake as a percent of body weight; CP=crude protein; ADF= acid detergent fiber; NDF=neutral detergent fiber; GE= gross energy; OMD= organic matter digestibility; DMD= dry matter digestibility

6.3.2 Apparent Total Tract Digestibility

There were no significant differences (P > 0.05) for OM digestibility (OMD) or apparent total tract DM digestibility between the different supplemented groups. This agrees with findings of Leupp et al. (2008) with steers, and Felix et al. (2012) with sheep, who both found that OMD was not affected by increasing levels of DDGS in diets. Numerically the OMD demonstrated that the control supplemented lambs had the greatest digestibility while the numerically greatest DM digestibility was for the DDGS supplemented group. This lack of difference for OMD and DM digestibility may be explained by the supplementation level of the current study (50% total diet), as other comparable research using finishing lambs to look at nutrition parameters of DDGS has set supplementation level at 65% of ration (Abdelrahim et al. 2014) and 76 % of ration (Shauer et al. 2008).

Calculated apparent nutrient digestibility values are shown in Table 6.1. Numerically GE digestibility was highest in the DDGS supplemented diets. This is most likely due to the fact that DDGS has a higher fat content than barley making more of these nutrients available for the animals to digest. CP and ADF were significantly higher for The DDGS supplemented calves compared to the control group. This is supported by Li et al. (2008) using heifers on finishing rations where they increased the dietary concentration of DDGS from 0% (control) to 35% replacing barley in diets. They found that the digestibility of CP, NDF, ADF and EE in the total digestive tract was significantly ($P<0.05$) greater for cattle fed 25% wheat DDGS than control animals. Li et al. (2008) had findings similar to the significant difference in ADF and CP digestibility found in this trial as DDGS was included in the diet. However, Felix et al. (2012) found that there was no difference in ADF digestibility as supplement levels of DDGS increased in growing lamb diets.

6.4 Conclusion

The sheep digestibility trial demonstrated that supplementing a forage based diet at 50% of total diet with either barley, DDGS or a 50:50 blend did not affect forage intake or apparent total tract digestion of OM, DM, or GE. There was no significant (P>0.05) effect on intake with the different supplementation strategies. Numerically, voluntary intake was highest in the DDGS fed lambs, and lowest in the control lambs. There were no significant differences (P>0.05) in the OM digestibility (OMD) or the apparent total tract DM digestibility between the 3 different supplemented groups. Numerically GE digestibility was greatest in the diets containing barley compared to the DDGS supplemented diets. Crude protein and ADF digestibility was significantly higher for DDGS supplemented lambs compared to control lambs.

In summary, the current trial demonstrated that supplementing lambs with either 100% barley compared a 50:50 mixture of barley and DDGS or 100% DDGS had no effect on DM intake. Digestibility of both CP and ADF were higher for the DDGS supplemented calves. These results suggest that DDGS can be supplemented for barley with similar results on DM intake and nutrient digestibility in lambs. The digestibility trial results using sheep as the model for cattle can be extrapolated to suggest similar results if steers were used (Colucci et al.1984).

7.0 General Discussion and Conclusion

Kaliel and Kotowich (2002) estimate that winter feeding costs account for 60-65% of total production costs for cow calf producers. Therefore any savings made in the area of feed can make a difference on total cost of production. There has been much research focused on extending the grazing season by managing animals on pasture longer than what is considered the conventional grazing period, due to the cost savings involved (Johnson and Wand 1999; Riesterer et al. 2000). The use of perennial pastures to extend the grazing season often relies on forage stand management to ensure forage is available and grazed in a manner that optimizes the forage resources, taking into account forage quality at grazing and managing the forage stand for sustainability (Riesterer et al. 2000; Scarbrough et al. 2004). The objective of this research was to evaluate wheat based DDGS as a supplement for backgrounding calves while on extensive fall, winter, and summer grazing scenarios. Calf performance and forage utilization were evaluated as calves grazed stockpiled crested wheatgrass pasture in the fall, crested wheatgrass pasture in the summer, or while extensively winter bale grazing. Finally, voluntary intake and apparent total tract digestibility were measured using ram lambs housed in metabolic crates fed a similar representative diet as the fall, winter and summer trials. The hypothesis of these experiments was the wheat DDGS would be a comparable supplement in extensive backgrounding scenarios for backgrounding calves.

In the first experiment (EXP 1), backgrounding animals grazed stockpiled crested wheatgrass pasture in the fall and were supplemented with 3 different strategies; either a 70:30 blend of barley+canola meal, a 70:30 blend of barley+DDGS or a 100% DDGS supplement. All supplement strategies were formulated to meet energy and protein requirements of the calves and were formulated to accommodate a targeted gain of 0.82 kg per day. Forage quality of the crested wheatgrass decreased as the fall progressed which was expected (Bruynooghe 1997;

Baron et al. 2004). There was no significant ($p<0.05$) effect of supplementation strategy on calf forage utilization or performance. The lack of supplement effect was unexpected and may have been attributed to the short trial duration, only one year of available trial data and low supplementation levels (1.6 kg/hd d^{-1} or 0.7% BW).

The second grazing experiment (EXP 2) was a winter bale grazing study using the same animals in EXP 1 but completely re-randomized to the new treatment strategies. This study was completed over a 2 yr period. In the winter bale grazing trial, the 3 supplementation strategies used were 100% Barley, 100% DDGS and a 50:50 mix of barley and DDGS. There were no significant ($p<0.05$) effects of supplementation strategy on forage intake with the DDGS supplemented calves. Moore et al. (1999) concluded that supplementation would increase forage intake if forage intake was less than 1.75% of BW and that the forage TDN to CP ratio was less than 7:1. In the current trial, the forage intake of the animals was calculated to be 1.1% BW and the forage TDN to CP ratio was 7.2:1. These calculations indicate that supplementation may not have increased forage intake when considering that forage TDN to CP ratio was greater than 7. There was an observed trend ($P=0.07$) on ADG for calves supplemented with DDGS compared to the other treatments. Calculated predictions of NE_m and NE_g from Zinn and Shen (1998) suggest that energy supplied by the diets in the current trial where adequate in meeting net energy requirements. This could account for the lack of significant differences in animal performance and estimated intake between the three supplement strategies in this study.

The third grazing trial (EXP 3) was managing calves on crested wheatgrass pasture during the summer months. Calves used in the winter and fall trials (EXP 1 and 2) were used in this trial and again re- randomized and allocated to one of 3 different supplementation strategies. The supplementation strategies used were 100% barley, 100% DDGS and 50:50 mix of barley and DDGS. Similar to the fall grazing trial, pasture quality decreased as the trial and season progressed. There were no significant (P<0.05) effects of supplement on performance however, there was a difference (P=0.04) in pasture forage utilization. This significant difference in pasture utilization is in contrast to other studies and contradicts the predicted NE_m and NE_g from Adams (1995) and Zinn and Shen (1998) equations. This response could be due to the forage estimation technique used in the study of calculating forage utilization pre- and post-grazing (Jasmer and Holechek 1984) which may have been inaccurate. This may be explained by the fact that measurement of intake of individual grazing animals remains one of the fundamental challenges to improving efficiency of livestock production (Lukuyu et al. 2014).

The fourth trial (EXP 4) was a sheep digestibility trial using ram lambs as the model for to investigate the digestibility and intake parameters of 3 supplement strategies in a controlled environment with the ability to feed animals individually. The supplementation strategies used were similar to the field grazing trials, 100% barley, 100% DDGS and 50:50 blend of barley and DDGS. In this trial, there was no effect (P>0.05) on intake parameters of the 3 different supplementation strategies. This lack of significant results to increasing DDGS in diets is supported by other literature (Powers et al. 1995; Liu et al. 2000; Anderson et al. 2006; Kleinschmit et al. 2007; Van Emon et al. 2012; Abdelrahim et al. 2014). There was also no significant (P>0.05) differences for ADF and CP digestibility between the 3 supplemented diets. In addition, total tract OMD digestibility remained unaffected (P>0.05) by treatment. This suggests that animal performance would be similar among treatment groups.

The common similarity in the 4 trials is the lack of significant (P>0.05) performance and intake parameters among supplementation strategies with the exception of gain in the winter trail and utilization in the summer trial. With the lack of significant (P<0.05) effects on intake and animal performance this would suggest that DDGS can replace barley as a supplementation strategy for backgrounding cattle in year round extensive grazing scenarios. The economic analysis of supplementation also suggests that a major factor effecting using one supplement type over another is cost which would be influenced by the annual market price.

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APPENDIX A

Table A.1 Meteorological data for Termuende Research Ranch, Fall Grazing Trial year 2[z]

	Temperature °C			Precipitation (mm)	
Day	**Maximum**	**Minimum**	**Mean**	**Rain**	**Total**
23-Oct-09	9.0	-0.5	4.3	-	-
24-Oct-09	6.4	-1.9	2.3	2.4	2.4
25-Oct-09	5.6	-4.2	0.7	0.4	2.8
26-Oct-09	12.4	-5.0	3.7	-	2.8
27-Oct-09	3.8	1.5	2.7	1.6	4.4
28-Oct-09	2.3	0.3	1.3	2.0	6.4
29-Oct-09	3.4	-2.7	0.4	-	6.4
30-Oct-09	2.6	-1.6	0.5	-	6.4
31-Oct-09	0.9	-6.9	-3.0	-	6.4
01-Nov-09	6.0	-3.5	1.3	-	6.4
02-Nov-09	0.9	-10.9	-5.0	-	6.4
03-Nov-09	1.7	-7.1	-2.7	-	6.4
04-Nov-09	4.9	-7.1	-1.1	-	6.4
05-Nov-09	6.3	-7.8	-0.8	-	6.4
06-Nov-09	17.8	-0.7	8.6	-	6.4
07-Nov-09	9.5	-1.2	4.2	-	6.4
08-Nov-09	6.4	-4.3	1.1	-	6.4
09-Nov-09	9.1	-7.9	0.6	-	6.4
10-Nov-09	11.8	-4.9	3.5	-	6.4
11-Nov-09	7.8	-6.9	0.5	-	6.4
12-Nov-09	4.6	-7.2	-1.3	-	6.4
13-Nov-09	4.9	-10.7	-2.9	-	6.4
14-Nov-09	1.6	-12.1	-5.3	-	6.4
15-Nov-09	5.2	-10.6	-2.7	-	6.4
16-Nov-09	12.4	-5.4	3.5	-	6.4
17-Nov-09	16.2	-0.9	7.7	-	6.4
18-Nov-09	13.7	-3.8	5.0	-	6.4
19-Nov-09	8.0	-10.5	-1.3	-	6.4
20-Nov-09	9.2	-8.0	0.6	-	6.4
21-Nov-09	9.3	-1.5	3.9	-	6.4
22-Nov-09	4.7	-12.6	-4.0	-	6.4
23-Nov-09	1.4	-14.5	-6.6	-	6.4
Trial Average	6.9	-5.7	0.6		6.4

Table A.2 Meteorological data for Termuende Research Ranch, Bale Grazing Trial Year 1[z]

Day	Temperature °C			Precipitation (cm)	
	Maximum	Minimum	Mean	Snow[y]	Total
27-Nov-08	3.9	-11.8	-4.0	-	-
28-Nov-08	-0.5	-12.8	-6.7	-	-
29-Nov-08	3.0	-13.7	-5.4	-	-
30-Nov-08	0.6	-12.3	-5.9	-	-
01-Dec-08	5.3	-11.4	-3.1	-	-
02-Dec-08	2.2	-7.3	-2.6	-	-
03-Dec-08	-6.4	-13.2	-9.8	-	-
04-Dec-08	-9.9	-13.1	-11.5	1.6	1.6
05-Dec-08	-3.3	-12.4	-7.9	-	1.6
06-Dec-08	-10.6	-21.6	-16.1	4	5.6
07-Dec-08	-4.3	-19.3	-11.8	-	5.6
08-Dec-08	-11.5	-18.1	-14.8	3.2	8.8
09-Dec-08	-14.7	-21.1	-17.9	0.8	9.8
10-Dec-08	-8.5	-15.6	-12.1	-	9.8
11-Dec-08	-6.4	-17.8	-12.1	2	11.8
12-Dec-08	-2.3	-15.1	-8.7	-	11.8
13-Dec-08	-15.1	-30.0	-22.6	-	11.8
14-Dec-08	-28.9	-32.5	-30.7	-	11.8
15-Dec-08	-22.3	-30.9	-26.6	-	11.8
16-Dec-08	-19.6	-29.6	-24.6	-	11.8
17-Dec-08	-19.3	-32.5	-25.9	0.8	12.6
18-Dec-08	-21.9	-30.6	-26.3	1	13.6
19-Dec-08	-21.0	-23.5	-22.3	3	16.6
20-Dec-08	-22.1	-28.4	-25.3	2	18.6
21-Dec-08	-24.3	-36.4	-30.4	-	18.6
22-Dec-08	-23.9	-38.0	-31.0	-	18.6
23-Dec-08	-22.8	-33.3	-28.1	-	18.6
24-Dec-08	-19.8	-29.9	-24.9	-	18.6
25-Dec-08	-11.3	-29.4	-20.4	-	18.6
26-Dec-08	-12.9	-29.7	-21.3	-	18.6
27-Dec-08	-15.2	-30.5	-22.9	-	18.6
28-Dec-08	-7.5	-21.6	-14.6	3	21.6
29-Dec-08	-21.1	-31.7	-26.4	-	21.6
30-Dec-08	-17.9	-31.0	-24.5	-	21.6
31-Dec-08	-10.8	-31.5	-21.2	-	21.6
01-Jan-09	-15.7	-32.7	-24.2	-	21.6
02-Jan-09	-13.1	-33.2	-23.2	-	21.6
03-Jan-09	-17.5	-33.2	-25.4	6	27.6

04-Jan-09	-29.8	-40.1	-35.0	-	27.6
05-Jan-09	-13.6	-34.3	-24.0	0.6	28.2
06-Jan-09	-15.5	-22.2	-18.9	-	28.2
07-Jan-09	-16.3	-25.0	-20.7	-	28.2
08-Jan-09	-16.5	-29.5	-23.0	1.6	29.8
09-Jan-09	-14.5	-25.2	-19.9	-	29.8
10-Jan-09	-8.5	-21.7	-15.1	1	30.8
11-Jan-09	-7.5	-17.9	-12.7	-	30.8
12-Jan-09	-17.9	-23.2	-20.6	2	32.8
13-Jan-09	-17.5	-28.5	-23.0	-	32.8
14-Jan-09	-25.2	-41.2	-33.2	-	32.8
15-Jan-09	-14.7	-40.7	-27.7	-	32.8
16-Jan-09	1.1	-17.7	-8.3	-	32.8
17-Jan-09	0.2	-4.5	-2.2	-	32.8
18-Jan-09	4.0	-1.7	1.2	-	32.8
19-Jan-09	0.9	-15.1	-7.1	-	32.8
20-Jan-09	-0.7	-15.3	-8.0	-	32.8
21-Jan-09	-3.7	-16.6	-10.2	2	34.8
22-Jan-09	-8.5	-21.4	-15.0	-	34.8
23-Jan-09	-21.2	-27.8	-24.5	-	34.8
24-Jan-09	-21.7	-29.2	-25.5	-	34.8
25-Jan-09	-22.8	-29.6	-26.2	-	34.8
26-Jan-09	-18.1	-31.1	-24.6	-	34.8
27-Jan-09	-4.7	-29.5	-17.1	-	34.8
28-Jan-09	-4.9	-13.8	-9.4	2	36.8
29-Jan-09	-4.0	-17.1	-10.6	-	36.8
30-Jan-09	2.9	-4.1	-0.6	-	36.8
31-Jan-09	5.1	-5.5	-0.2	-	36.8
01-Feb-09	-4.9	-25.4	-15.2	-	36.8
02-Feb-09	-18.9	-33.0	-26.0	-	36.8
03-Feb-09	-14.1	-23.8	-19.0	-	36.8
04-Feb-09	3.7	-14.8	-5.6	-	36.8
05-Feb-09	-4.1	-14.4	-9.3	-	36.8
06-Feb-09	-2.4	-11.7	-7.1	3	39.8
07-Feb-09	-1.7	-13.7	-7.7	-	39.8
08-Feb-09	-0.8	-11.8	-6.3	-	39.8
09-Feb-09	-2.5	-14.4	-8.5	-	39.8
10-Feb-09	-2.8	-5.4	-4.1	-	39.8
11-Feb-09	-5.4	-11.3	-8.4	2	41.8
12-Feb-09	-11.1	-20.6	-15.9	-	41.8
13-Feb-09	-16.4	-22.8	-19.6	-	41.8

14-Feb-09	-17.2	-28.6	-22.9	-	41.8
15-Feb-09	-21.1	-31.4	-26.3	-	41.8
16-Feb-09	-12.2	-26.3	-19.3	3.8	45.6
17-Feb-09	-11.7	-22.4	-17.1	-	45.6
18-Feb-09	-18.0	-26.0	-22.0	-	45.6
19-Feb-09	-9.3	-23.5	-16.4	-	45.6
20-Feb-09	-10.1	-18.8	-14.5	0.6	46.2
21-Feb-09	-7.8	-18.5	-13.2	-	46.2
22-Feb-09	-9.6	-15.3	-12.5	-	46.2
23-Feb-09	-10.2	-17.0	-13.6	-	46.2
24-Feb-09	-11.9	-20.6	-16.3	9.8	56
25-Feb-09	-20.6	-25.3	-23.0	1	57
26-Feb-09	-19.7	-36.1	-27.9	-	57
27-Feb-09	-16.6	-37.8	-27.2	-	57
28-Feb-09	-16.2	-28.5	-22.4	-	57
01-Mar-09	-12.2	-30.7	-21.5	-	57
02-Mar-09	-6.5	-15.8	-11.2	-	57
03-Mar-09	-0.2	-13.6	-6.9	-	57
04-Mar-09	4.4	-11.0	-3.3	-	57
05-Mar-09	-3.5	-14.2	-8.9	4	61
06-Mar-09	-14.2	-28.2	-21.2	-	61
07-Mar-09	-5.6	-29.3	-17.5	-	61
08-Mar-09	-11.3	-21.9	-16.6	-	61
09-Mar-09	-21.3	-28.9	-25.1	-	61
10-Mar-09	-23.5	-30.5	-27.0	-	61
11-Mar-09	-19.0	-32.4	-25.7	-	61
12-Mar-09	-7.1	-28.1	-17.6	-	61
13-Mar-09	2.5	-10.2	-3.9	-	61
14-Mar-09	0.8	-12.7	-6.0	-	61
15-Mar-09	-0.5	-13.7	-7.1	-	61
Trial Average	-10.8	-22.6	-16.7		61

[z]Meteorological data from Agri-Environment Services Branch, Agriculture and Agri-Food Canada
[y]Snow of ground, measured early morning (Environment Canada National Weather Archive, Esk, SK)

Table B.2 Meteorological data for Termuende Research Ranch, Bale grazing Trial Tear 2[z]

	Temperature °C			Precipitation (cm)	
Day	**Maximum**	**Minimum**	**Mean**	**Snow[y]**	**Total**
24-Nov-09	2.6	-11.3	-4.4	-	-
25-Nov-09	2.3	-10.2	-4.0	-	-
26-Nov-09	2.1	-10.0	-4.0	-	-
27-Nov-09	3.7	-3.6	0.1	-	-
28-Nov-09	2.7	-6.6	-2.0	-	-
29-Nov-09	2.3	-14.8	-6.3	-	-
30-Nov-09	4.5	-0.6	2.0	1.0	1.0
01-Dec-09	-0.4	-8.2	-4.3	0.6	1.6
02-Dec-09	-6.7	-13.4	-10.1	-	1.6
03-Dec-09	-10.7	-21.4	-16.1	-	1.6
04-Dec-09	-14.7	-24.2	-19.5	-	1.6
05-Dec-09	-9.7	-17.8	-13.8	-	1.6
06-Dec-09	-10.4	-19.5	-15.0	-	1.6
07-Dec-09	-16.6	-30.0	-23.3	-	1.6
08-Dec-09	-20.9	-34.0	-27.5	-	1.6
09-Dec-09	-21.1	-31.8	-26.5	0.4	2.0
10-Dec-09	-19.7	-27.8	-23.8	0.4	2.4
11-Dec-09	-15.7	-29.2	-22.5	-	2.4
12-Dec-09	-27.5	-32.0	-29.8	-	2.4
13-Dec-09	-26.4	-33.1	-29.8	-	2.4
14-Dec-09	-24.9	-29.7	-27.3	-	2.4
15-Dec-09	-17.8	-34.0	-25.9	-	2.4
16-Dec-09	-11.1	-22.3	-16.7	-	2.4
17-Dec-09	-9.0	-20.7	-14.9	-	2.4
18-Dec-09	-9.1	-20.0	-14.6	-	2.4
19-Dec-09	-6.8	-10.9	-8.9	0.6	3.0
20-Dec-09	-5.2	-19.4	-12.3	-	3.0
21-Dec-09	-15.1	-24.1	-19.6	1.0	4.0
22-Dec-09	-7.9	-15.1	-11.5	-	4.0
23-Dec-09	-8.1	-20.4	-14.3	2.0	6.0
24-Dec-09	-19.1	-25.2	-22.2	-	6.0
25-Dec-09	-19.4	-25.8	-22.6	-	6.0
26-Dec-09	-16.5	-27.3	-21.9	-	6.0
27-Dec-09	-8.5	-25.9	-17.2	-	6.0
28-Dec-09	-9.2	-14.5	-11.9	0.8	6.8
29-Dec-09	-11.4	-21.6	-16.5	0.6	7.4
30-Dec-09	-12.6	-19.4	-16.0	-	7.4
31-Dec-09	-18.0	-29.3	-23.7	-	7.4

01-Jan-10	-17.8	-39.1	-28.5	-	7.4
02-Jan-10	-12.3	-18.2	-15.3	-	7.4
03-Jan-10	-11.7	-25.4	-18.6	-	7.4
04-Jan-10	-12.6	-25.0	-18.8	2.0	9.4
05-Jan-10	-13.3	-17.7	-15.5	-	9.4
06-Jan-10	-17.7	-27.5	-22.6	-	9.4
07-Jan-10	-25.3	-34.9	-30.1	-	9.4
08-Jan-10	-20.3	-30.2	-25.3	-	9.4
09-Jan-10	-8.9	-22.1	-15.5	-	9.4
10-Jan-10	-6.2	-15.9	-11.1	-	9.4
11-Jan-10	-2.6	-15.4	-9.0	-	9.4
12-Jan-10	3.3	-7.0	-1.9	-	9.4
13-Jan-10	3.3	-5.8	-1.3	-	9.4
14-Jan-10	-3.9	-13.0	-8.5	-	9.4
15-Jan-10	4.1	-12.6	-4.3	-	9.4
16-Jan-10	4.4	-3.0	0.7	-	9.4
17-Jan-10	-2.5	-15.1	-8.8	-	9.4
18-Jan-10	-2.0	-15.9	-9.0	-	9.4
19-Jan-10	-5.0	-11.4	-8.2	-	9.4
20-Jan-10	-4.9	-8.3	-6.6	1.0	10.4
21-Jan-10	-3.1	-5.1	-4.1	-	10.4
22-Jan-10	-3.0	-4.0	-3.5	-	10.4
23-Jan-10	-3.3	-4.8	-4.1	-	10.4
24-Jan-10	-4.4	-10.7	-7.6	-	10.4
25-Jan-10	-10.6	-16.0	-13.3	28.0	38.4
26-Jan-10	-15.3	-20.2	-17.8	-	38.4
27-Jan-10	-17.3	-21.3	-19.3	-	38.4
28-Jan-10	-20.3	-29.3	-24.8	-	38.4
29-Jan-10	-17.1	-27.8	-22.5	-	38.4
30-Jan-10	-11.5	-17.6	-14.6	-	38.4
31-Jan-10	-15.6	-26.2	-20.9	-	38.4
01-Feb-10	-15.2	-23.0	-19.1	3.0	41.4
02-Feb-10	-11.4	-16.1	-13.8	1.5	42.9
03-Feb-10	-11.2	-22.4	-16.8	-	42.9
04-Feb-10	-8.3	-19.5	-13.9	-	42.9
05-Feb-10	-6.4	-12.4	-9.4	-	42.9
06-Feb-10	-5.7	-9.9	-7.8	-	42.9
07-Feb-10	-9.5	-27.2	-18.4	-	42.9
08-Feb-10	-20.6	-28.3	-24.5	-	42.9
09-Feb-10	-15.7	-29.9	-22.8	-	42.9
10-Feb-10	-13.7	-25.9	-19.8	-	42.9

11-Feb-10	-5.8	-13.7	-9.8	-	42.9
12-Feb-10	-8.6	-20.1	-14.4	-	42.9
13-Feb-10	-13.8	-21.6	-17.7	-	42.9
14-Feb-10	-18.8	-27.8	-23.3	-	42.9
15-Feb-10	-15.2	-29.1	-22.2	-	42.9
16-Feb-10	-4.5	-18.3	-11.4	-	42.9
17-Feb-10	-7.4	-16.2	-11.8	-	42.9
18-Feb-10	-7.5	-17.8	-12.7	-	42.9
19-Feb-10	-5.5	-8.4	-7.0	-	42.9
20-Feb-10	-6.9	-15.0	-11.0	-	42.9
21-Feb-10	-10.4	-25.7	-18.1	-	42.9
22-Feb-10	-6.4	-20.3	-13.4	-	42.9
23-Feb-10	-11.9	-30.0	-21.0	-	42.9
24-Feb-10	-8.5	-15.6	-12.1	-	42.9
25-Feb-10	-5.6	-18.3	-12.0	-	42.9
26-Feb-10	-12.7	-21.2	-17.0	-	42.9
27-Feb-10	-4.7	-21.8	-13.3	2.0	44.9
28-Feb-10	-5.4	-12.8	-9.1	-	44.9
01-Mar-10	-3.8	-15.5	-9.7	-	44.9
02-Mar-10	-5.6	-16.8	-11.2	-	44.9
03-Mar-10	-5.2	-14.0	-9.6	-	44.9
04-Mar-10	-1.7	-12.1	-6.9	-	44.9
05-Mar-10	-3.7	-14.8	-9.3	-	44.9
06-Mar-10	-1.1	-9.3	-5.2	-	44.9
07-Mar-10	0.1	-12.2	-6.1	-	44.9
08-Mar-10	0.3	-1.4	-0.6	-	44.9
09-Mar-10	0.7	-1.3	-0.3	-	44.9
10-Mar-10	0.0	-1.0	-0.5	-	44.9
11-Mar-10	1.1	-7.4	-3.2	-	44.9
12-Mar-10	4.0	-8.0	-2.0	-	44.9
13-Mar-10	2.7	-7.4	-2.4	-	44.9
14-Mar-10	3.5	-5.5	-1.0	-	44.9
Trial Average	-8.7	-18.3	-13.5		44.9

[z]Meteorological data from Agri-Environment Services Branch, Agriculture and Agri-Food Canada
[y]Snow of ground, measured early morning (Environment Canada National Weather Archive, Esk, SK)

Table A.3 Meteorological data for Termuende Research Ranch, Summer Grazing Trial Year 1[z]

	Temperature °C			Precipitation (mm)	
Day	**Maximum**	**Minimum**	**Mean**	**Rain**	**Total**
27-May-09	22.5	5.7	14.1	-	-
28-May-09	20.5	1.6	11.1	-	-
29-May-09	20.3	2.8	11.6	1.8	1.8
30-May-09	30.0	0.5	15.3	-	1.8
31-May-09	21.9	5.6	13.8	-	1.8
01-Jun-09	15.1	5.3	10.2	-	1.8
02-Jun-09	19.9	0.0	10.0	-	1.8
03-Jun-09	25.2	5.2	15.2	-	1.8
04-Jun-09	16.1	6.6	11.4	-	1.8
05-Jun-09	12.2	1.2	6.7	-	1.8
06-Jun-09	10.1	4.4	7.3	3.2	5.0
07-Jun-09	10.3	4.0	7.2	2.2	7.2
08-Jun-09	12.0	5.0	8.5	4.6	11.8
09-Jun-09	13.1	2.9	8.0	2.6	14.4
10-Jun-09	15.8	2.1	9.0	-	14.4
11-Jun-09	22.3	5.7	14.0	-	14.4
12-Jun-09	22.7	8.6	15.7	-	14.4
13-Jun-09	27.2	3.9	15.6	1.8	16.2
14-Jun-09	31.6	9.7	20.7	-	16.2
15-Jun-09	30.2	13.6	21.9	-	16.2
16-Jun-09	28.8	10.8	19.8	-	16.2
17-Jun-09	31.1	12.0	21.6	24.6	40.8
18-Jun-09	27.2	11.8	19.5	-	40.8
19-Jun-09	23.9	11.5	17.7	-	40.8
20-Jun-09	24.2	8.7	16.5	12.0	52.8
21-Jun-09	19.9	14.5	17.2	15.4	68.2
22-Jun-09	20.4	13.7	17.1	10.6	78.8
23-Jun-09	23.2	11.6	17.4	-	78.8
24-Jun-09	24.6	10.8	17.7	-	78.8
25-Jun-09	30.3	7.6	19.0	-	78.8
26-Jun-09	25.5	11.7	18.6	5.4	84.2
Trial Average	21.9	7.1	14.5		84.2

[z]Meteorological data from Agri-Environment Services Branch, Agriculture and Agri-Food Canada

Table B.3 Meteorological data for Termuende Research Ranch, Summer Grazing Trial Year 2[z]

	Temperature °C			Precipitation (mm)	
Day	**Maximum**	**Minimum**	**Mean**	**Rain**	**Total**
26-May-10	12.5	3.7	8.1	-	-
27-May-10	10.9	2.6	6.75	2.8	2.8
28-May-10	9.6	5.7	7.65	1	3.8
29-May-10	8.4	5.6	7	4.8	8.6
30-May-10	11.1	3.7	7.4	4	12.6
31-May-10	10.1	2.5	6.3	-	12.6
01-Jun-10	17	3.3	10.15	-	12.6
02-Jun-10	20.3	4.3	12.3	-	12.6
03-Jun-10	16.9	9.1	13	33.6	46.2
04-Jun-10	17.1	7.3	12.2	-	46.2
05-Jun-10	20.3	9.8	15.05	5.8	52
06-Jun-10	22.6	9.4	16	6.2	58.2
07-Jun-10	16.7	7.2	11.95	17.6	75.8
08-Jun-10	15.5	10.5	13	5	80.8
09-Jun-10	14.3	6.2	10.25	13.2	94
10-Jun-10	10	9.2	9.6	18.8	112.8
11-Jun-10	11.3	8.4	9.85	-	112.8
12-Jun-10	17.9	8.9	13.4	-	112.8
13-Jun-10	21.7	7	14.35	-	112.8
14-Jun-10	25	8.8	16.9	-	112.8
15-Jun-10	21.8	10.9	16.35	-	112.8
16-Jun-10	19.5	14.1	16.8	15.6	128.4
17-Jun-10	17.1	14.2	15.65	24	152.4
18-Jun-10	21.4	12.8	17.1	-	152.4
19-Jun-10	21.5	11.3	16.4	5	157.4
20-Jun-10	23.5	9.4	16.45	-	157.4
21-Jun-10	25.5	11.1	18.3	3.6	161
22-Jun-10	24	14.3	19.15	-	161
23-Jun-10	23.9	14.3	19.1	-	161
24-Jun-10	25.9	13.1	19.5	12	173
25-Jun-10	27.2	12.4	19.8	-	173
26-Jun-10	23.8	12.9	18.35	-	173
27-Jun-10	23.1	12.3	17.7	-	173
28-Jun-10	24.3	12.9	18.6	-	173
29-Jun-10	27.8	14.2	21	1	174
30-Jun-10	29.7	16	22.85	-	174
01-Jul-10	25.3	13.5	19.4	15.2	189.2
02-Jul-10	25.3	15.4	20.35	-	189.2

03-Jul-10	25.4	12.3	18.85	-	189.2
04-Jul-10	25.3	10.2	17.75	-	189.2
05-Jul-10	17.8	13.5	15.65	-	189.2
06-Jul-10	21.2	11	16.1	-	189.2
Trial average	19.8	9.9	14.8		189.2

[z]Meteorological data from Agri-Environment Services Branch, Agriculture and Agri-Food Canada

APPEDIX A: Equations

Equation A.1 Penn State grass-legume equation (Adams 1995)

Digestible Energy (Mcal kg-1; DE) = 0.04409 x (4.898 + [1.044 – {0.0119 x ADF(%)}] x 89.796

Equation A.2 Penn State cereal grain equation (Adams 1995)

Digestible Energy (Mcal kg-1; DE) = 0.04409 x (4.898 + [0.9265 – {0.00793 x ADF(%)}] x 89.796

Equation A.3 Estimated forage intake (Mertens 1987)

Dry matter intake (DMI) = (1.2% x body weight) / (% NDF)