University of Alberta

Determining the Nutritional and Economic Impact of Feed Waste When Wintering Beef Cows in Central Alberta

by

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A thesis submitted to the Faculty of Graduate Studies and Research in
partial fulfillment of the requirements for the degree of

Master of Science

in

Animal Science

Agricultural, Food and Nutritional Science

Fall, 2009
Edmonton, Alberta

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ABSTRACT

Two experiments measured winter feed waste when cows were fed forage on snow. In the first experiment, feed waste was different ($P<0.01$) when alfalfa meadow brome mixed hay was fed by bale unroller or bale processor; waste was12.9% vs.19.2%, protein losses were 23.3% and 21.5% respectfully. Feed waste, nutrient replacement and additional equipment costs increased winter feeding costs by $52.50 and $56.25 per head respectfully for a 175 day feeding period. Hay processed into portable bunk feeders, experienced 0% feed waste. In the second experiment, feed waste when barley cereal silage fed either as high moisture round bale silage or chopped pit silage was fed on snow was not different ($P>0.05$) at 23.2% and 26.8% respectfully. When chopped barley cereal silage or high moisture round bale silage was fed into bunks, feed waste was 0%. Protein losses were 27.1% and 24.2% for the pit and round bale silage. Feed waste, nutrient replacement and additional equipment costs increased winter feeding costs by $164.50 for pit silage and $126.00 for bale silage over a 175 day feeding period.

Quote:

“The task is not so much to see what no one yet has seen, but to think what nobody yet has thought about that which everyone sees".

Schopenhauer.

ACKNOWLDEGEMENTS

I would like to thank the many people that supported me to make this program a possibility. First, to my wife Yvonne, children Erin, Todd and Robyn, your patience and understanding was greatly appreciated during the time I was away from home completing course work at the University, and for the many evenings that were spent writing the thesis. To Dr. Okine and the members of the committee, Dr. Oba, Dr. Goonewardene and Duane McCartney many thanks for your guidance, wisdom and support that helped me successfully complete the program. I would also like to thank Alberta Agriculture and Rural Development for providing partial funding the project, to the management that supported me in this endeavor, and to co-workers Ken Ziegler, Pat Ramsey, Gordon Hutton thank you for helping in the planning of the project and to Allan Macaulay for helping with the day to day regular work load in the second year of the trial. To the technicians Kyle Greenwood and Nancy Elbing, the hours that were put in made the job much easier. The Alberta Beef Producers' provided generous financial support towards the operating costs of the second year of the research project was greatly appreciated. Without the assistance and cooperation of the Lacombe Research Station and staff of the beef unit; to supply animals and a location for the study, and assistance with the day to day feeding of the animals, this research would not have been possible.

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ADF	acid detergent fibre
ADG	average daily gain
ADIN	acid detergent insoluble nitrogen
ADL	acid detergent lignin
AF	as fed
BW	body weight
cm	Centimeters
CP	crude protein
CPS	chopped pit silage
DCP	digestible crude protein
DE	digestible energy
DM	dry matter
DMI	dry matter intake
ha	Hectare
IVDDM	*in vitro* digestible dry matter
IVDMD	*in vitro* dry matter disappearance
IVTD	*in vitro* true disappearance
kg	Kilogram
Kg/d	kilograms per day

LIST OF ABBREVIATIONS (page 2)

kg/m^3	kilogram per cubic metre
L	Litres
MBAH	meadow brome alfalfa hay
NDF	neutral detergent fibre
RBS	round bale silage
RFV	relative feed value
T	tonne (2204 pounds)
TDDM	total digestible dry matter
TMR	total mixed ration

Chapter 1: General Introduction and Research Hypothesis

1.1 Introduction

The cow calf industry in western Canada in the late 1880's was typically a low input extensive grazing operation. In southern Alberta, cows grazed year round, fended for themselves against predators and consumed dormant forage during the winter. For example, a news article in the Macleod Gazette, August 4, 1885 recommended that farmers and ranchers cut and store some hay for winter use when the snow became too deep for animals to graze, or to feed stock during severe storms (Brado, 1984) was considered foolish by local ranchers. Severe winters of 1886–87 and 1906 – 07 resulted in 25 to 75% of the cow population starving or freezing to death (Brado, 1984). This caused a paradigm shift where producers recognized that forage needed to be harvested annually, specifically for winter feeding to prevent catastrophic losses in the future.

Over the years, the cow calf industry developed and progressed into an integrated, highly capitalized, and intensive industry. Managing the winter feeding program and providing supplemental feed is a common practice to maintain good body condition in the breeding stock. On many operations, calving season has moved from spring or early summer to January through March. This paradigm shift occurred to produce larger calves for the fall markets and to obtain higher cash return from the calves sold (Dobson, 2009). (Appendix A, Chart 1). This change in calving date requires higher quality feed to meet higher nutritional requirements of the lactating cow, and increased the total amount of winter feed required, as well.

Another shift has been the increase in the number of cows per herd over the last 50 to 60 years. Economy of scale has forced farmers and ranchers to move towards larger herds (Statistics Canada 2008), (Appendix A, Table 1) resulting in a change in feeding methods and technologies. Labour costs contribute 8 to 10% of the annual cost of raising a calf, (Kaliel, 2007) and is a limited resource, so feeding systems are now mechanized to reduce time, labour requirements, and expense.

Many aspects of feeding cattle have changed over the years. Winter feed costs are 35% to 40% of the total cost of raising a calf annually (Kaliel, 2008). Thus a reduction in feed waste should be beneficial to producers, yet the amount of feed waste associated with feeding cattle over the winter has been accepted as a cost of "doing business." An Alberta Agriculture and Rural Development survey (Appendix A, Survey 1) conducted in 2004 showed, of the 293 completed surveys, (Appendix A, Survey 2), 88% of the respondents believed that feed waste was less than 10% of the feed provided to the animals.

New technologies have emerged over the last 10 years claiming to be more efficient than earlier feeding methods. Adoption of the mechanical bale processor as a method of delivering feedstuffs to feed larger cattle herds reduced time, labour, and overall cost of feed delivery. Using a machine that chops and delivers baled long forage is a way to "reduce hay use by 20%", and "reduce costs when providing a palatable ration to cows" (Haybuster advertising brochure, 2007). Another company indicates "a 30% reduction in feed costs, much less sorting, trampling or soiling of feed, and fewer concentrates needed to be fed to balance rations" (Highline advertising brochure, 2007).

The statements above imply that waste is reduced, feed quality is improved and overall cost of feeding cows over winter will be less when long forage is delivered to the wintering cow herd using a bale processor.

Unfortunately, bale processors "were designed to shred straw and provide a uniform bedding layer for feedlot or cow calf animals. There is no research done on how a bale processor will impact the feeding of wintering beef cows" (pers. comm. Al Goehring, Dura Tech Industries, 2004. Jamestown, ND).

Indeed, no references were found in the scientific journals comparing feed delivery systems, associated costs related to each system, feed waste or overall feeding efficiencies.

This study was initiated to compare three feed delivery systems, the bale unroller, bale processor and silage delivery truck, to deliver meadow brome hay, high moisture meadow brome hay, and high moisture barley greenfeed silage bales or chopped pit silage to wintering beef cows fed on snow. These feeds and feeding systems were chosen because they are commonly used by cow calf operations in western Canada and north western United States.

The objectives of the study were:

- To establish the amount of physical feed waste that occurs when feeding on snow.
- To compare three feed delivery systems and how the delivery system impacted feed loss for the three forage type provided.
- To determine the impact of feed waste on the amount of nutrients consumed by the animals compared to the "calculated" nutrients provided.
- To quantify which feed fractions are lost in the wasted feed.
- To calculate the impact of feed waste on profitability using the feeding systems in question and forages available.

- To provide possible management alternatives to reduce the amount of physical waste or minimize the impact of the wasted feed on individual farm or ranch operation.

1.2 Research hypothesis

Feed waste has been measured when stationary feed containment devices were used (Lechtenberg *et al.,* 1974; Blasi *et al.,* 1993 Buskirk, *et al.,* 2003) when feeding wintering cows. The design of the feeder contributed to the amount of forage lost (Comerford *et al.,* 1994) and the amount of forage placed out for consumption also impacted total feed loss (Mader *et al.,* 1999). Concerns with experimental design and physical limitations of feed waste collection has been questioned in the past (Brasche and Russell, 1998) and admissions by other researchers (Buskirk *et al.,* 2003) confirms that measurements can be difficult. In addition, cows showed a preference in the type of feed that they consume (Jungnitsch, 2008) and this also influenced the amount of waste that occurred.

With the presence of many different factors influencing feed waste, we hypothesized that different forage delivery systems influence the amount of feed waste that occurs when feeding cows on snow over winter when providing the same feedstuff. We also hypothesized that the physical characteristics of different feedstuffs influence the amount of waste that occurs and that there is a direct impact on the nutrition of the animal when feed wastage occurs.

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Chapter 2: Literature Review

2.1 Introduction

Prior to the mid 1970's the use of small square or small round bales or haystack feeding systems were common on cow calf operations (McCartney, 2005). Bales were stored under sheds or covered with tarps. If not covered, stacks were constructed to minimize surface area to prevent moisture penetration and minimize weather damage. Forages were typically fed either in fence line feeders, portable feeders, or hand fed onto the ground (McCartney, 2005).

By the late 1960's, large round bale systems were being adopted by farmers and ranchers (Beacom, 1991). Hand feeding of forage was replaced by mechanized methods. Large round bales required less labour and proved to be a more time efficient method to feed cows (Baxter *et al.,* 1986). At the same time, the number of cows per herd almost doubled, (Anonymous**,** Statistics Canada; Agriculture Census Report, 2008) (Appendix A, Table *I*) thus, total forage requirements per farm increased. With larger size bales, and an increased number of bales needed to meet total winter feed requirements, it became more difficult to store the winter feed supply under sheds, or to protect bales from the weather. Thus, more forage was stored outdoors unprotected from the weather.

Use of bale feeders or other feed restraining devices declined with the adoption of bale processors in the early 1990's. Bale processors are used to transport baled forage to the feeding area; a large diameter rotor with flail knives chops the bales of long forage through a grate, resulting in the processed material to be shorter in length than the original material. The flails pulls the forage through the grate and by centrifugal force discharges it out the side of the machine. A deflector shield can deflect the discharged forage either into windrows or allow the material to be thrown up to 50 feet when bedding a manure pack (Anonymous, 2007) for a Bale King Vortex bale processor. With the bale processor, forage is either delivered into fenceline or portable feeders, but the vast majority of cattle are fed on the ground or snow without any physical barrier to prevent trampling losses.

2.2 Forage harvest losses

The amount of forage available for livestock consumption is dependant on many factors. Growing conditions, crop variety, insect or disease infestation, soil fertility, harvesting, storage and feeding losses impact the amount of forage produced per hectare (ha) (Savoie *et al.,* 1982; Johnson *et al.,* 1984; Belyea *et al.,* 1985; Landblom *et al.,* 2007).

Alfalfa crops harvested as hay or silage experienced harvest and storage losses. When the crop was harvested as silage, hay stacks, small square bales, large round bales and small round bales, dry matter (DM) losses of 9.9, 10.6, 16.6, 30.2 and 33.6% respectively were measured (Johnson *et. al.,* 1984). Harvest losses associated with the production of large round bales of alfalfa hay were 10 to 50 kilograms (kg)/ha for mowing, 20 to 30 kg/ha for late conditioning, and 50 to 80 kg/ha for raking (Savoie *et al.,* 1982). These losses accounted for 5 to 7% DM loss per ha.

A 5% DM loss occurs per pass when alfalfa windrows were turned with a rake (Anderson *et al.,* 1981). When a 3.7 m alfalfa windrow is baled using a large round baler, 14%, DM loss occurred. When the windrows were doubled or tripled by combining 2 or 3 windrows into one, DM losses were reduced to 12 and 5% respectively when baled (Anderson *et. al.,* 1980). An 8.0% DM loss occurred due to respiration and shatter loss when alfalfa was cut at early flowering stage (Collins, 1991). When alfalfa from the same field, cut at the same time but exposed to 25 mm of rainfall prior to harvest, this resulted in an additional 11.7% DM loss. In this study, Collins found that the total forage weight consisted of 61% stems and 39% leaves. By contrast, 62% of the total nitrogen was contained in the leaves. Leaves also accounted for 78% of the respiration and shattering losses. Loss of soluble protein from leaf material (measured as Nitrogen) resulted in an increase in the acid detergent fibre (ADF) and neutral detergent fibre (NDF) concentrations and reduced *in vitro* dry matter disappearance (IVDMD) (Appendix A, Table *II*).

Rainfall during the field drying stage reduced IVDMD by 7% and *in vitro* true digestibility (IVTD) by 6% compared to hay that was not rained on. Rainfall accounted for 60% of the DM and quality losses which indicated that rainfall has a greater impact on forage quality loss than respiration and shattering losses.

2.3 Forage storage losses

In 1998, 150 million tons of hay valued at 12 billion dollars was produced in the United States (Ball *et al.,* 1998). With an adequate hay supply, Ball *et al.,* (1998) speculated that producers pay little attention to quality losses that occur during storage and waste during feeding.

In 2004 and 2005, Canada produced approximately 8.2 million ha of tame hay (Anonymous, Statistics Canada, 2006). Using the ten year average yield of 5 tonnes per ha (Savoie, 1996), approximately 41 million tonnes of perennial forage is produced annually.

Dry matter (DM) losses cannot be totally eliminated, but efforts to minimize DM losses are beneficial (Buckmaster, 1993a). In freshly chopped material, initial DM losses of 2 to 16% are due to plant respiration which continues until the material has wilted and moisture content is below 38 to 40% (Robertson, 1983). When no rainfall occurred during the wilting and field drying of common vetch, soluble sugars and carbohydrates by weight accounted for 1.5 to 2.8% of the total DM loss (Trevino *et al.,* 1993). Carbohydrate losses were greater from the stem material than the leaves because the leaf dried faster, minimizing respiratory losses. Glucose, fructose and starch concentrations were lower after respiration and sucrose levels were higher both in the stem and leaf material (Trevino *et al.,* 1993).

In baled hay with moisture content greater than 15%, DM storage losses are due to bacteria, fungi, and yeast respiration that consume nonstructural carbohydrates from the plant tissue to produce carbon dioxide, water and heat (Harrigan *et al.,* 1994). Primary losses are sucrose and other sugars. When the carbohydrates were depleted, proteins and fats are alternate energy sources for the microbes but are consumed at a slower rate.

If bales were moved into storage areas and stacked into piles or placed into rows within a day or two of baling, heat generated within the bale was contained within the stack. Heat production occurred in all bales, but storage temperatures above 36 ^{o}C occurred when moisture content at baling exceeded 18% (Buckmaster *et al.,* 1988).

High temperatures can be generated within the first 20 d after baling and immediate stacking. When hay temperatures rise above 35 ^{o}C, the Maillard reaction starts (Buckmaster *et. al.,* 1988). As temperatures increase above this level, sugars and other carbohydrates are polymerized with amino acids resulting in the formation of acid detergent insoluble nitrogen (ADIN). Longer periods of time with high temperatures increase the amount of damage to the hay, reducing the amount of available protein to animals (Buckmaster *et al.,* 1988). At 35^{o} C, ADIN formation is measurable, but is definitive when temperatures exceed 50^{o} C (Yu, 1976). The Maillard reaction can occur at the low temperatures, but it requires a longer period of time for the damage to become apparent (Goering *et al.,* 1972).

2.4 Impact of storage location on DM loss

Large round bales stored indoors, stacked round bales stored outdoors and covered with plastic, uncovered bales stored outdoors, had DM losses of 2.0, 6.0, and 15.0% respectively (Belyea *et al.,* 1985). In Alberta, DM losses over a 290-d fall winter storage period resulted in DM losses of 5.7, 10.2 and 1.3% for large round bales stored outdoors uncovered, coated with a mixture of beef tallow and pork fat, or covered with a plastic tarp (Hand *et al.,* 1994). In a Kentucky study over a 240-d storage period, DM storage losses in large round bales were 3.8 and 9.1% when stored indoors and outdoors respectively (Collins *et al.,* 1987).

Weathering caused significant damage to orchardgrass tall fescue mixed hay stored outdoors in Indiana (Lechtenberg *et al.,* 1974). When they removed the visibly damaged hay, DM losses of 22.3, 14.5, 12.6 and 21.0% occurred in compressed stacks, untied large round bales, tied round bales and small round bales respectively.

Several different techniques used to tie round bales, along with the use of stack covering material decreased weather damage during the storage of large round bales of tall fescue hay in Kentucky (Collins *et al.,* 1995). DM losses were 3.6, 5.7, 10.6, and 18.2% for solid plastic wrapped bales stored outdoors, twine wrapped bales stored indoors, plastic mesh wrapped bales stored on the ground outdoors and twine tied bales stored outdoors on the ground respectively.

Net wrapped bales stored outdoors shed more rainfall than twine tied bales, and retained more DM than the twine wrapped bales stored outdoors (Anstey and Arduser, 1991).

Large round bales of alfalfa grass hay made in Wisconsin, were stored outdoors on the ground tied with sisal twine, plastic twine, net wrap to the edge of the bale, net wrap covering the edge of the bale, bale bonnets (plastic covers) or stored indoors experienced 19.5, 10.6, 7.2, 7.2, 4.5 and 1.9% DM loss over a 12 month period respectively (Shinners *et al.,* 2002).

2.5 Impact of weathering on hay quality

In New Zealand, one of the reasons for using round bales was to eliminate the need for indoor hay storage from February to July which is their spring to summer seasons (Scales *et al.,* 1978). This experiment evaluated the impact of 348 mm of rainfall on large round bales stored outdoors. DM storage losses (including inedible waste) were 30.7 and 39.5% for grass hay and alfalfa hay respectively. Storage losses were less for soft core bales compared to hard core bales although no values were provided.

In western Canada, 70% of the commercial hay producers and beef operations use the round bale system (Beacom, 1991). Storage of soft core bales outdoors was superior to hard core bales in retaining feed quality (McCartney, 2005). When hay was baled at 23% moisture, the soft core baler resulted in 4% less DM loss compared to the hard core baler (Beacom, 1991).

In an attempt to quantify DM loss due to weather damage in Louisiana, large round hay bales of hay were stored hay in a barn (control), stored outdoors and placed on the ground, or on a 20 cm gravel base, on tires, on wooden racks covered with plastic, and on wooden racks with the hay left unprotected. After seven months, DM losses were 2.3, 27.6, 31.2, 35.4, 26.0, and 12.6% respectively. Precipitation received over the storage period was 500 mm (Verma *et al.,* 1981). In the high humidity and rainfall areas, storing hay under a barn proved very effective to prevent dry matter loss. Storing hay unprotected outdoors, in contact with the ground or a gravel base resulted in high DM losses. Placing bales on tires did not prevent contact with the ground and losses were also high. Placing plastic over the bales trapped moisture; when the moisture condensed on the inside of the plastic, it migrated into the bales causing high DM loss. It appeared that if the bales were kept off the ground which prevented moisture migration into the bottom of the bale and allowed to breathe and dissipate moisture as seen with the unprotected bales placed on wooded racks DM losses were reduced.

2.6 Damage to hay during storage

Large round bales stored outdoors without cover were observed to incur visual deterioration on the upper exposed hay layer or thatch, and on the bottom layers that were in contact with the soil (Schott *et el.,* 1992). Bales stored outdoors unprotected tend to flatten out or squat during storage (Appendix A, Figure 1).

Outer layer top spoilage or weather damage of round bales contributed significantly to deterioration of quality (Buckmaster, 1993b). For example: a 5-foot diameter bale with 5 inches of outer layer spoilage involves 30% of the total bale weight The smaller the diameter of the bale, the larger the percentage of bale weight held in the outer layers (Appendix A, Figure 2).

Use of a soybean oil based product, Balebutter® to protect bales from weathering prevented moisture migration and deterioration of quality in the outer layers of the upper half of the bales (Smith *et al.,* 1989). Application time of 10 minutes per bale and volume of product required per bale are limiting acceptance of this weather proofing product.

When comparing high density bales with 190 kilograms per cubic metre(kg/m^3) bound with net wrap to those tied with twine, more moisture was retained in the twine tied bales than for those tied by net wrap (Taylor *et al.,* 1994). Net wrapped bales remained rounder and had a smoother surface which shed more water than a twine tied bale. Bales stored outdoors and tied either with sisal twine or plastic net wrap increased NDF concentration by 7.1and 4.6% respectively after a 270-d storage period.

2.7 Weather damaged hay reduced free choice forage consumption

Weathering alters forage quality in the bale. Bales stored indoors have very little change in physical or chemical composition (Russell *et al.,* 1990). Unprotected hay bales stored outdoors had weather damage in the outer 20 cm layer of the bale. This layer represented 31% of the bale weight. The inner portion or core of the bale representing 69% of the total weight was not damaged. Total hay consumption increased from 66 to 74% of the bale weight for bales covered by plastic sheets and stored outdoors on tires compared to those stored on the ground. When the wasted material was evaluated, it was noted that entire plants were wasted from the weathered portion of the bale, while stems and stalks were primarily wasted from the undamaged portion of the bale.

Type of material used to tie or bind bales and the condition of the ground that alfalfa smooth bromegrass bales are placed upon, influenced DM recovery and hay quality (Russell *et al.,* 1990). In both the high density bales (189 kg/m^3) and low density bales (146kg/m^3), the outer 30 cm of hay representing 61% of total bale weight had lower

DM and *in vitro* digestible dry matter (IVDDM) than the undamaged internal material after 4 or 9 months of storage. Concentrations of ADF, NDF, acid detergent lignin (ADL), and ADIN increased after storage compared to the original baled forage material (Appendix A, Table *III*).

Net-wrapped alfalfa meadow brome mixed hay bales had higher DM recovery than twine-tied bales (93.0 vs. 88.3%) and higher IVDDM (86.6 vs. 81.5%) (Russell *et. al.,*1990). Dry matter recovery from high density bales stored on 15 cm of crushed rock was not significantly different (91.9 vs. 89.4%) than bales stored on the ground. Low density bales had a lower core DM than high density bales (73.1 vs. 81.0%) indicating that more moisture migrated into the centre of the bale. Low density bales placed on rock improved DM content in the outer 30-cm layer of the bale compared to those placed on the ground (82.5 vs.78.2%). High-density net-wrapped bales did not appear to sag, thus minimizing contact between the bale and the ground. Moisture difference was minimal between the outer layer and the inner core. In a sheep feeding trial, hay refusal from low density twine wrapped bales stored on the ground was 4.8% compared to 6.8% for hay when fed at 90% of ad libitum intake levels determined during the adaptation period prior to the feeding period(Appendix A, Table *IV*) (Russell *et. al.,* 1990).

For bales stored over winter outdoors on the ground in Indiana, 57% of the total spoilage was attributed to the contact between the hay bale and soil (Lechtenberg *et al.,* 1980). In Alberta, bottom bale spoilage in contact with the soil was 1.0% of bale weight when placed on a 10 cm gravel base, and 1.3% on the soil base after a 290-d storage period with 150 mm rain and 300 mm snow (Hand *et al.,* 1994). The differences in spoilage between the two studies could be attributed to the freeze-thaw cycles that occur in Indiana over the winter.

2.8 Digestibility and nutrient change in weather damaged hay

Physical deterioration of bale quality occurred in the outer 20 cm layer of hay (Anderson *et al.,* 1981). This influences crude protein (CP), IVDMD, ADF and unavailable protein in bales stored outdoors (Appendix A, Table *V*).

A mixed alfalfa bromegrass hay stored outdoors but protected with a 0.15mm plastic cover, and stored on tires, increased DM recovery and in vitro digestible dry matter (IVDDM) than hay stored outdoors unprotected on the ground (Brasche and Russell, 1988). Hay covered with plastic had lower NDF, ADF and ADL concentrations, and increased IVDDM by 10.7% compared to the control.

Unprotected grass hay in large round bales, compressed stacks, and small round bales lost 8.2, 12.6, and 16.9 % of the total digestible dry matter (TDDM) respectively during the winter storage period (Lechtenberg *et al.,* 1974). Higher 48-h IVDMD measurements (technique from Barnes *et al.,* 1971) were obtained from the freshly cut material compared to hay stored indoors (56.5 vs. 54.4 %) whereas the weathered portion of the hay had an IVDMD of 36.8 %, significantly lower than the un-weathered hay portion. Loss of the soluble feed fractions reduced IVDMD.

In another study, harvested alfalfa hay bales split into two lots were either stored indoors or outdoors (Anderson *et al,* 1981). The hay stored indoors compared to outdoors have higher IVDMD (61.8 to 54.6%) after winter storage. Bales stored outdoors for 90 d had a reduction in IVDMD of 0.5% for every 1% increase in moisture over a threshold of 20% at baling (Collins *et al.,* 1987).

Reductions in DM digestibility may be attributed to heating. Nonstructural carbohydrate concentration reduced from 2.9 to 1.0%, and NDF concentration increased from 48.0 to 54.1% (Johnson *et al.,* 1984). The ADF and NDF fractions in stored hay were higher after storage, indicating that a soluble portion of the hay was lost to a greater extent.

Hay stored outdoors in rows or stacked pyramid style had significantly higher *($P<0.05$)* ADF and cellulose but significantly lower digestible energy (DE) compared to bales stored in a shed (Atwal *et al.,* 1984). In his experiment, Atwal *et. al.,* 1984 found that voluntary feed intake for the hay stored in rows or in a pyramid were 34.6 and 37.5% lower than for hay stored under shed respectively. Recovery of DM, DE, CP and digestible crude protein (DCP) were 52, 49, 45 and 37% lower for hay stored outdoors in a row than that stored under shed respectively. Hay stored in a pyramid stack and covered with plastic for 30-d reduced losses for the parameters mentioned above by 35, 41, 27 and 29% respectively.

Rainfall penetration and moisture migration from the ground into large round bales reduces forage quality. Mixed alfalfa grass hay bales experienced more damage compared to meadow brome hay bales as measured by increased NDF values from 48.8 to 50.9% in the mixed hay bales and 64.9 to 66.0% in the brome hay bales from harvest to the end of the storage period, respectively. It was speculated that the brome hay bales shed more rainfall and wicked up less moisture from the ground compared to the alfalfa grass hay (Brasche and Russell, 1988).

Bales stored on tires and the upper half of the bale covered with a plastic sheet resulted in a higher IVDDM than unprotected hay stored on the ground (56.3%, vs. 54.4%) (Appendix A, Table *VI*) (Brasche and Russell, 1988).

When the mixed hay and brome hay from the Brache and Russel storage experiment, was fed to mature cows, average daily gain (ADG) was not significantly different (0.1 vs. 0.08 kg/d) with the differences in IVDDM observed (Brasche and Russell, 1998).

Bales stored in a barn, stored on gravel and covered with plastic, stored on gravel uncovered, and stored on ground uncovered had visibly weathered hay that amounted to 1, 4, 8, and 23% of the total bale weight respectively (Werk *et al.,* 1998). Storing hay outdoors unprotected, resulted in hay deterioration to occur beyond the visibly damaged layers of the bale. Damage was greater for the leaf fraction of the bale compared to the stems. Crude protein in the leaf material stripped from hay stored in the barn or from the bottom 15 cm of bales stored unprotected outdoors on ground was 30.2 and 22% and relative feed value (RFV) was 232 and 86 respectively. The change in hay quality was attributed to chemical changes in leaf composition, not to the difference in leaf to stem ratio (Werk *et al.,* 1998).

Forage material collected from an internal bale depth of 10 to 35cm from the bottom side of unprotected bales stored outdoors on the ground had a normal visual appearance. However, chemical analysis of this material indicated that deterioration had occurred even when it is undetected visually. (Appendix A, Table *VII*)

2.9 Feeding systems and feed waste

When hay is trampled on, or contaminated with manure, animals refuse to consume the forage (Bell and Martz, 1976). Without physical restraints to restrict access to the feed, 40% of the hay was wasted (Kallenbach, 2000). Cows scattered hay from unprotected large round bales over a 6.6m diameter area from the centre of where the bale is placed. Waste was reduced to 6, 14 and 6% when bale rings, electric fence or fence line bunks were used respectively.

Buskirk *et al.,* (2003) reported feeding losses associated with cone, ring, portable trailer, and cradle feeders were 3.5, 6.1, 11.4, and 14.6% respectively. Hay provided in this study was stored under shelter and protected from weather damage prior to feeding.

Feeding hay without a physical restriction such as a rack to prevent the cows from trampling on the hay resulted in 22.6 % to 38.6 % waste (Lechtenberg *et al.,* 1974). If a rack was used as a physical restraint, waste was reduced to 3.7%. Preventing animals from trampling on the hay reduced DM losses to 6%. When forage density in the bale increased, shape was retained longer and less trampled occurred, thus less exposure to excretal contamination.

When mature sheep were fed baled sorghum hay free choice for 40-d in drylot, 24.7% of hay stored on pallets and covered with plastic prior to feeding was wasted when no physical restraints were used (Huston and Bales, 1988).

Wheat hay bales fed long unrolled on the ground, processed with a bale processor and fed on the ground, or processed and fed into a bunk resulted in 23, 13, and 8% waste respectively (Blasi *et al.,* 1993). Feeding hybrid Sudangrass in the same manner had 22, 16 and 11% waste (Blasi *et al.,* 1993). In both experiments, rakes were used to collect the wasted forage. Much of the leaf material was not captured thus the reported waste underestimated the actual loss, especially for the Sudangrass (Blasi pers. comm., Dec 2007).

When a 40% straw and 60% hay ration was processed through a bale processor and fed on snow to mature beef cows in central Saskatchewan, 19.8% waste was measured in the spring (Jungnitsch, 2008). The vast majority 76.8% of the feed loss was from straw remaining in the feeding windrow. Cows showed a preference to consume the hay.

2.10 Access and feeding devices, and feed wastage

2.10.1 Animal behavior

Feeding devices such as the standard ring, cone, trailer and cradle feeder designs affect access to feed by influencing the frequency of normal or abnormal entrances (an animal accessing feed above the top rail of the device) and the antagonistic behavior (displacement of animals by another), and impact feed waste patterns (Buskirk *et al.,* 2003). Compared to the cone feeder, the amount of wasted feed was increased by 2-fold for the ring feeders, and by 4-fold for the trailer feeder and cradle feeders. (Appendix A, figure 3).

Animals eating from the cone and ring feeders were more able to closely mimic a head down grazing position than those eating from the trailer and cradle feeder (Buskirk *et al.,* 2003). It was observed, when cattle consume feed with a head down position, less hay was thrown up over the shoulder or onto their backs. In feeders with offset angled rails that required the cows to turn their heads at an angle to access the feed, were partially constrained and not able to pull away from the feeder or drag the feed out onto the ground.

Cows eating out of the cradle feeder had three times as many antagonistic behaviors compared to the other feeder types, and frequency of entry into the feeder was increased by 4-fold. The number of abnormal eating behaviors such as pulling hay from the bale above the top rail was also the highest for the cradle feeder.

Feed losses were positively correlated with the frequency of antagonistic behaviors, number of entrances to the feeder and duration of feeding (Buskirk *et al.,* 2003).

Animals tend to toss more hay when they consume feeds with their heads up in a horizontal position rather than in a head down position commonplace with eating off the ground or pasture. This behavior wastes 5 to 10% of the feed (Albright, 1993).

2.10.2 Access to feed

Providing a high quality round hay bales for 3, 6 or 9 hours per day did not reduce body condition score (BCS) on pregnant cows compared to unlimited access (Miller *et al.,* 2007). By limiting access to the forage to 3 hours, total DMI was reduced from 13.3 kg DM to 8.0 kg DM, and waste was reduced from 39.5 to 33%. Feed costs were reduced by $0.66 per head per day when hay was valued at $88/T.

2.10.3 Feeder type

Amount of feed waste was significantly different with the type of bale feeder used; conventional ring feeders had 8% loss whereas the cone type ring feeder had only 1.9% DM loss (Comerford *et al.,* 1994).

Feed waste can be as high as 50% if storage and feeding systems are not properly managed,12% feed waste occurs when animals are fed daily with a bale shredder, and as high as 40% loss can occur if a 3-d supply of feed is provided at one time (Kallenbach, 2000).

Cattle can waste 33% of the forage provided when animals have unlimited access to hay (Mader *et al.,* 1999). Losses caused by trampling, over consumption, fouling and use for bedding can result in 25 to 45% losses when hay is fed ad libitum. In 120 days, 317 kg of hay is over consumed when cows have ad libitum access to hay (Mader *et al.,* 1999).

Extension publications from many jurisdictions in North America and other countries indicate that feed waste is a management problem (Appendix A, Table *VIII*). It should not be treated as a unique problem of one specific geographic region.

Use of stockpiled perennial forages or winter grazing of windrowed annual forages is a feeding option available to producers (Volesky *et al.,* 2002). Feed waste from windrowed forage consumed by 200 kg calves averaged 29.0% while it was 12.5% when bales were fed in a feeder. When cows were forced to graze the remaining forage refused by the calves, total DM waste was reduced to 4%.

Many attempts have been made to measure feed waste but some data may not be accurate (Brasche and Russell, 1988). "Dry matter intake (DMI) measured by feed refusal may be inaccurate because of inconsistencies in obtaining and weighing refused feed that is trampled and contaminated with feces and soil." "Hay that fell onto the concrete surrounding the feeder was considered wasted. Care was taken to avoid collection of manure, although some contamination was unavoidable" (Buskirk *et al.,* 2003). Collecting wasted feed is not an exact science. Due to technical limitations, amounts of waste reported are at best a “good estimate” of what has occurred.

2.11 Nutrient content of different plant botanical fractions

Various plant fractions contain different concentrations of protein, fibre, energy, and minerals. Alfalfa leaves are nutritionally distinct from the stems (Appendix A, Table *IX*) (Sheaffer *et al.,* 2000).

Accumulation of ADF and NDF in the stem is more rapid than in leaves at the same stage of maturity. Leaf tissue retains higher energy and protein concentration and digestibility than the stems. Alfalfa plants staged at early flowering and late flowering maturity have 52 and 46% of total plant weight as leaves (Sheaffer *et al.,* 2000).

Annual cereal crops consist of different plant fractions such as grain, spike, awn, leaf blade, sheath, nodes and internodes (Khorasani *et al.,* 1997). All of the fractions contribute to total DM yield (Appendix A, Table *X*) and overall forage quality. When used for silage, crops are harvested at the mid dough stage to maximize yield, while maintaining adequate quality for beef cows and feedlot rations.

Barley grown for grain production in the Black soil zone of Alberta results in 0.97 tonnes of straw and 0.14 tonnes of chaff being harvestable per tonne of grain threshed (Hartman, 1999). Fibre and macro nutrient content of chaff, straw and grain vary greatly. A ten year summary of feed test results for straw, chaff and grain from the Alberta Soil and Feed testing laboratory confirms the differences in nutrient content (Suleiman, 1987) (Appendix A, Table *XI*).

2.12 Impact of storage and feeding system on animal performance

When forage deteriorates during storage, a reduction in voluntary DMI is most apparent with high producing dairy cows (Baxter *et al.,* 1986). Any reduction in nutrient concentration or availability decreases milk production and BW. Dairy cows in mid lactation (113 days in milk) fed unprotected hay stored outdoors versus hay stored under a shed decreased milk yield (15.9 vs. 16.7 kg/d) and body weight (BW) gain (0.51 vs.0.73 kilograms per day (kg/d) over a 56-d feeding period. If the cows were fed round bales of mixed alfalfa grass hay stored outdoors covered with 6-mm plastic, and placed on tires, cows had similar milk production as those fed hay stored under a shed (Baxter *et al.,* 1986).

Dairy cows fed hay stored as conventional square bales stored inside, round bales stored inside, round bales stored outside covered, round bales stored outside on tires, or round bales stored outside on the ground resulted in feed waste of 7.1, 15.5, 11.6, 26.0 and 33.4% respectively (Appendix A, Table *XII*) (Baxter *et al.,* 1986).

Feeding an alfalfa bromegrass mixed hay stored in a barn, and shredded into feed bunks to continental cross type beef cows in med pregnancy tended to decrease total DM intake by 0.21 kg (7.97 vs. 8.13 kg) compared to the same forage fed as long hay (Brasche *et al.,* 1988). Animals fed hay shredded into feed bunks improved ADG by 0.09 kg/d compared to those fed hay in ring feeders with unrestricted access. Shredded hay that was stored outdoors had a reduced DM intake by 1.71 kg/d (7.81 vs. 9.52 kg) compared to the same forage fed as long hay. The use of feedbunks reduced waste compared to the use of ring feeders, increased feed intake and contributed to the greater ADG, but no measurements of waste were reported (Brasche *et al.,* 1988).

When feeding on ground, wastage or hay stored indoors and hay stored unprotected outdoors was 12.5 and 24.7% respectively (Belyea *et al.,* 1985). When storage DM losses and feeding losses are calculated, total losses were 39.7% for unprotected hay stored outdoors. The DMI was reduced by 0.23 kg/d per 100 kg BW when weather damaged hay was fed, which decreased ADG by 0.13 to 0.23 kg/d compared to feeding covered hay. Belyea recommends that large round bales be stored under sheds to prevent substantial economic losses.

Lactating dairy cows require a high energy, high protein ration to maintain milk production (Rupel *et al.,* 1930). When cows were fed a constant amount of concentrate, feeding hay chopped with a stationary bale processor versus long forage did not affect 4% fat corrected milk yield, but the chopped hay reduced ADG from 0.18 to 0.109 kg/d (Rupel *et al.,* 1930).

There is a negative relationship between dietary NDF and voluntary feed intake in dairy cows (Khorasani *et al.,* 1997). Khorasani (1997) reported that a 1% increase in dietary NDF concentration in early bloom alfalfa resulted in a DMI decrease of 0.95 kg.

Rams fed alfalfa-bromegrass mixed hay bales wrapped with plastic mesh improved DMI (% of BW) by 25.2% for high density bales (189 kg /m^3) and 16.2% for low density bales (146 kg/m^3) compared with those fed hay bales wrapped with sisal twine (Russell *et al,* 1990). Storing bales on crushed rock compared to the ground improved DMI 13.5% for the high density bales and 18.9% for the low density bales (Appendix A, Table *XIII*). DM digestion coefficients were not affected by bale type, tying material or ground contact. Greater DMI decreased NDF and cellulose digestion due to a higher passage rate (Russell *et al.,* 1990).

In a feeding trial, alternate windrows of a grass forage were harvested either as chopped pit silage or stored as long forage in round bale silage at 70% DM (Morrison *et al.,* 1981). The use of alternate rows for the different storage methods was an attempt to obtain similar initial forage quality for all treatments. Calves weighing 350 kg were fed limited amounts of barley and free choice silage for 140-d. Weight gains were 6% lower (0.93 vs. 0.99 kg) lower and DM intake was lower (5.6 vs. 5.7 kg) for the baled silage compared to the chopped silage.

The DM field losses were less for soft core bales than hard core bales when the hay was baled at 24% moisture (5.2 vs. 12.3%), but no differences in DM losses were observed when bales were made at 18% moisture (Beacom, 1991). However, soft core bales at either moisture content had higher DM storage losses than hard core bales when stored outdoors (8.1 vs. 5.4%). Steers weighing 250 kg were fed hay baled with either a soft or hard core baler for 84 days. Hay bales from both types of balers stored indoors resulted in the highest ADG. When both types of bales were stored unprotected outdoors, the feeding of soft core bales resulted in higher gains than hard core bales.

2.13 Economics

Winter feed costs are influenced by geographic location, climatic conditions, number of grazing days, size of the operation, feed availability, feed cost and operating costs associated with feed delivery systems (Miller *et al.,* 2001). Annual feed costs attribute 65% of the total cost of maintaining a cow herd (Hughes, 1989). Differences in winter feed costs between low and high cost producers was up to $1 per head per day. This difference in feed costs accounted for 50% of the variation in profitability for cow calf operations (Miller *et al.,* 2001).

Winter feed costs vary from 32 to 44% of the total annual cost of raising a calf in Alberta due to variation in length of the winter feeding period (Kaliel, 2004, 2008). Increasing the number of grazing days and reducing days of winter feeding minimizes the overall feeding costs for the operation. Winter feed costs vary from year to year due to the number of days that feed is provided and geographical location within the province (Appendix A, Table *XIV*) (Kaliel, 2007a; 2007b). Kaliel found that winter feed costs varied from \$120 per cow to \$295 per cow depending on the year.

The time and expense of delivering feed to wintering cows contributes to total winter feed cost. Shredding hay into bunks reduces feed costs when larger herds are fed and hay prices are high (Appendix A, Table *XV*) (Blasi *et al.,* 1993). Blasi *et al.,* 1993included an operating expense for the bale process at \$17 per hour which included depreciation, interest, and repairs, for 150 hours of bale processor use on an annual basis. No additional equipment costs were included in the calculations. If tractor, fuel and labour were valued at \$91 per hour and were included in the total operating cost, the calculated net savings in Blasi's results need to be reduced by \$13,650 (Appendix B). Profitability is eliminated from all scenarios presented by Blasi *et al.,* 1993 when total equipment operating costs are used.

Use of a tapered round bale feeder to hold alfalfa grass hay bales was 10.2% more efficient in reducing feed loss compared to rolling out bales on the ground or 15.2% more efficient than using a bale processor (Landblom *et al.,* 2007). Feed losses were extrapolated from the change in BCS using energy formulas. When a 100 cow herd was fed over a 135 day feeding period, feed costs were \$8,945, \$9,858, and \$10,311 for the bale feeder, unrolled hay and shredded hay respectively (Landblom *et al.,* 2007).

In the United States, larger beef cow herds have a lower cost of production compared to smaller cow herds (Hughes, 1989). Producers that controlled input costs by using resources efficiently resulted in higher production efficiencies and highest profitability. The number one factor influencing profitability is feed and feed related expenses. A $77 difference in winter feed costs existed between the least profitable and most profitable herds ($111 vs. $188 per head) (Hughes, 1989). Farms with 100 to 499 cows had the highest gross value of production and highest net income due to economies of scale.

When lactating dairy cows were fed hay unprotected from the environment and stored on the ground, more hay was required to produce the same amount of milk compared to cows fed hay that was stored under a shed or protected from the environment (Harrigan *et al.,* 1994). A cow producing 7,600 litres (L) of milk per year had increased feed costs of $47 when unprotected alfalfa hay was fed ad libitum. Reduced forage intake due to weather damage when stored outdoors resulted in 5.4% lower milk production compared to the same hay stored indoors. Net revenue was reduced by $155 per cow. When outdoor stored hay was chopped and used in a total mixed ration (TMR), waste decreased, but overall costs increased when machinery ownership and operating costs were included in the calculations. Improved DM recovery and reduced waste did not offset the additional equipment expenses (Harrigan *et al.,* 1994).

2.14 Cost of stored feed systems

Cost of producing and making hay, baling and moving the feed to a storage yard in Nebraska averaged $63.00/ha (Volesky *et al.,* 2002). An additional $20.00 per ha was required to move the hay bales out of the feed yard and into feeders. This is 37% more expensive than providing forage in a swath grazing system. When labour and fencing materials were considered, feeding costs were reduced by $0.14 per head /d or $20 over a 142 d winter grazing period. When yield per ha is considered, swath grazing improves net return over baling and feeding the hay by $93.00/ha. When the same amount of hay was baled and sold off the farm, profit was $174.00/ha (Volesky *et al.,* 2002)

Increasing the number of days that animals are able to graze forage reduces total winter feeding costs. Total cash costs for swath grazing cows was $70.00 less expensive than traditional feeding, and $56.70 less than alternate day feeding for a 100 day feeding period. Labour and machinery costs were the main difference between the different feeding systems. Feed waste averaged 14.6% over the three year trial and was included in total cash costs (McCartney *et al.,* 2004).

Swath grazing cows consumed 17.5 and 21.2% more DE than the traditional feeding and alternate day feeding animals. The extra energy was required to offset the extra walking, foraging and maintaining body temperature under winter conditions. Feed costs for swath grazing, daily feeding, or alternate day feeding was $0.34, $0.69 and $0.60 per head per day, respectively (McCartney *et. al.,* 2004). In an Alberta Agriculture survey, the cost of swath grazing was $0.50/d less expensive than delivering stored feed to cows due to a reduction in yardage costs (Anonymous, 2004).

Traditional winter feeding system or alternate day feeding of an energy source requires 38.4 and 20.9% more labour than swath grazing (Kaliel and Kotowich, 2002). With 1.26 million cows present in northern Alberta, swath grazing could potentially save $66.8 to 88.2 million annually for equipment and labour expenses.

Livestock feeding costs has been an area of research for many years. Early results for feed processing concluded that feeding chopped alfalfa hay to dairy cattle versus long hay reduced the value of the hay by $0.09 per ton and reduced ADG from 0.186 kg per day to 0.108 kg /d (Rupel *et al.,* 1930). Chopping of long forage into smaller particles increases the rate of ruminal digestion which in turn reduces pH. A reduction in pH reduces milk production (Allen, 1997.)

Beef cows fed chopped lower quality coarse forages improved DMI, but equipment costs eliminated any net savings obtained from reduced waste (Rupel *et. al.,* 1930).

In a more recent study, feeding a herd of one hundred cows for 130 days over winter required machinery, fuel and manpower (Jungnitsch 2008). Work done at the Termuende Research Ranch, Western Beef Development Centre (University of Saskatchewan) showed that tub grinding greenfeed increased feeding costs by $16.60 /T. Use of a bale shredder to deliver feed onto snow every third to fourth day required 33 hours of operating time over the winter feeding period. This Saskatchewan study found that fuel, equipment and labour added $33.54 per cow to feeding costs. In contrast, an Alberta Agriculture study showed that 78% of the respondents provided forage on a daily basis (Kaliel, 2004), thus feeding cost estimates from the Jungnitsch trial are underestimating the equipment, fuel and labour charges when livestock is fed daily.

In North Dakota, a cow calf profitability study found the number one critical success factor for profitability was total feed costs (Hughes 1989). A $1 increase in feed costs reduced profit by $2.48, when feed accounts for 69% of the cost of raising a calf.

2.15 Conclusions

In the literature, feed cost is identified as the major expense that occurs in a beef operation. From the review, storing harvested forage either as dry hay under a shed, as individual bales wrapped in plastic or in plastic tubes are three preferred storage methods to minimize DM losses, increase DMI and maintain high IVDMD levels in the stored forage. Storing bales on the ground with no protection from rainfall, or adverse weather is the least preferred method of keeping hay for winter feeding.

Preserved forage stored as silage is the preferred method over dry hay systems in areas with unpredictable rainfall during the harvesting period. The loss of soluble carbohydrates, proteins and vitamin precursors from hay in the windrow prior to harvest reduces the quality of feed and increases the cost of providing a balanced ration.

There are many models developed to calculate the impact of higher feed expenses on long term profitability of a beef operation. These models indicate that for every dollar increase in feed cost, the negative impact on profit is three to four dollars. Minimizing feed costs is a primary driver in maintaining a profitable cow calf operation.

Economic evaluation of feeding systems requires the estimation of feed costs, amount fed per day and number of days that harvested forage is supplied to the cows as the cost of the winter feeding program. There are some studies that include the cost of delivering hay as a part of the cost of the winter feeding program, but those references have not allocated sufficient expenses to account for feed delivery costs. There is very little data available in the literature to accurately estimate feed delivery costs.

There is minimal data available in the literature evaluating the amount of feed waste that occurs when forage is delivered into feeders, fenceline bunks or portable hay trailers. Some articles report feed waste as a gross amount or percentage loss relative to the total amount fed to animals. Feed waste was either estimated visually, or measured after collection off an artificial barrier such as a cement pad using a rake and shovel, but three problems are associated with these procedures:

1) Placing feeders onto a hard surface such as concrete creates an artificial environment, which may not reflect actual conditions, underestimating the amount of feed waste.
2) Visual estimations of loss can be different compared to actual (measured) losses.
3) Feed waste is measured as a gross amount. No consideration is given to which part of the plant is lost as waste and the impact the loss has on the nutritional of the animal.

2.15.1 Issues addressed in present research

There is no published information to quantify the amount of feed waste when harvested forages are fed on snow to wintering beef cows. One of the gaps in the literature is the amount of feed waste that results when feeding three commonly used feedstuffs; meadow brome alfalfa mixed hay, chopped barley pit silage and high moisture round bale barley silage in western Canada and northwestern United States. This work is required to establish a baseline for feed waste. Without this information, we cannot attempt any calculations to quantify the economic impact of these losses on cow calf operations.

New feeding technology has been typically considered as a way to improve operational efficiency and reduce costs. The acceptance of the bale processor across western Canada over the last 10 years has been touted as a more efficient way to feed wintering cows. Unfortunately, there are no scientific articles found to support this claim. Another gap in the literature is the lack of comparisons between commonly used feed delivery systems; the bale unroller, bale processor and chopped silage delivery truck, to determine if one is more effective in preventing or reducing the amount of waste. This information is needed to help producers make a more informed decision on how to use each system and to improve efficiencies in their operations.

In the few published journal articles that evaluated the impact feed waste on animal nutrition, the feed losses were calculated by multiplying the amount of feed loss (actual or estimated weight) by the nutrient concentration analyzed on the original feedstuff. In these calculations, it was assumed that the wasted feed has identical nutrient composition as the original feed, but this supposition has not been proven to be true.

In this study, we are challenging the supposition that all feed fractions are lost at the same rate. It is necessary to breakdown total feed delivered into various plant fractions and to determine the amount of nutrients supplied to the animals by each fraction. When the wasted feed is collected and separated back into individual fractions, nutrient losses can be calculated with more precision. These new protocols should improve our capability to calculate whether or not feed waste impacts the ration sufficiently to not meet the nutritional requirements of the animals.

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Chapter 3: Determining the amount and impact of feed waste when feeding bred heifers with two different feed delivery systems

3.1 Introduction

Feed costs represent 60 – 65% of the total annual cost of keeping a cow (Hughes 1989; Miller 2001; Kaliel, 2004). As preserved or stored winter feed is provided to cows for a longer period, profitability of the operation is adversely affected (Blasi *et al.,* 1993). Preventing feed loss reduces total winter feeding costs (Landblom *et al.,* 2007) which in turn impacts profitability of the operation (Hughes, 1989). Indeed, on cow calf operations, reducing winter feed costs is identified as one way to improve profitability (Kaliel 2007).

Producers do not recognize feed waste as an expense that can be managed by changing feeding systems, feed restraining devices or type of forage provided. The practice of feeding on snow has become a common practice in western Canada and parts of Northwest United States over the last decade (McCartney, 2005). Use of the bale processor to shred baled forage and place the processed forage into windrows has been advertised as a more efficient method of feeding cows than feeding long forage (Highline Manufacturing, 2007 Vonda SK,; Bale King, 2007 Regina, SK,; Duratec Industries, 2007, Jamestown, ND).

No references were found in the literature that quantified the amount of feed waste that occurred when providing a common forage diet onto snow with different feeding systems.

3.2 Objectives

The primary objective of this study was to measure the amount of feed that is wasted when bred heifers were fed a constant amount of mixed 90% meadow brome 10%

alfalfa hay (MBAH) onto snow. The second objective was to compare the amount of waste that occurs using two feed delivery systems; the bale unroller (old technology) and the bale processor (new technology). The third objective was to evaluate the impact of feed waste on the quality of the diet actually consumed by animals and overall winter feed costs including machinery. The final objective was to evaluate portable bunk feeders as a part of an alternate feeding method to reduce feed waste and in turn reduce winter feeding costs.

3.3 Materials and methods

To make this experiment relevant to the cow calf sector, every attempt was made to use typical management practices used throughout the province. The first cut MBAH was harvested in early July, which is typical for cow calf operators to cut hay in central Alberta.

3.3.1 Experimental design

The treatments were shredding MBAH in feed bunks, shredded MBAH onto snow, and unrolled MBAH onto snow. These treatments were evaluated for 4 weeks. The variables analyzed, using a randomized block design were proportion of coarse and fine material in the forage at time of delivery and in the waste material, and total amount (kg DM) of wasted feed. The blocking factor was week. Individual samples were analyzed for crude protein, Ca, P, Mg, K, Na, ADF and NDF.

3.3.2 Location

The experiment was conducted at a 3 ha perennial grass pasture (part of NW 13 40 27 W4) at the beef research unit located at the Agriculture and Agri-Food Canada Research Station in Lacombe, Alberta. This paddock was grazed over the summer and early fall. The remaining forage was 5cm or less in height at the end of the grazing season.

3.3.3 Livestock and feed

Fifty-five two year old bred heifers with an average weight of 521 kg were used in the experiment. These animals were raised on perennial grass pasture during the summer and fall of 2004.

The MBAH used in the trial was grown at the Agriculture and Agri-Food Canada Research Station in Lacombe, Alberta. The harvested hay bales were stacked under a pole hay shed within a week of harvest and remained under the shed throughout the winter. The bales were stacked in columns of three, with the flat surface of the first (bottom) bale in contact with the gravel floor with two additional bales stacked vertically on top of the first. Plywood sheets 1.3m wide x 2.6m long were attached horizontally to the outside of the poles just under the roof trusses. This provided a 1.3m barrier to protect the tops of the columns by preventing rain or snow from entering under the eves and the resulting moisture from penetrating the bales.

3.3.4 Feed waste collection mats

A geotextile fabric manufactured by Propex Geosynthetics (Chattanooga, TN.) was selected as the collection system for the wasted feed. The fabric is porous allowing liquids such as urine or melting snow to pass through the material, but has sufficient strength to withstand mechanical damage from animal hoof activity or equipment traveling over the fabric during feeding events.

Rolls of geotextile fabric (100m x 4.57m) were cut into 2.13m x 4.57m or 7.62m x 4.57m mats. The smaller mats were used for the snow feeding events and the larger mats were placed under the portable feed bunks.

Mats were placed on the ground prior to snowfall (Appendix C), stapled into place in rows of four (samples per replicate). There was a 9m space between feeding mats to allow collection of delivered feed samples from different segments of the bale. Each mat was identified by a numbered plastic ear tag placed in one corner of the fabric. Location of the collection mats was marked by placing survey flags in the centre of the small mats and at either end of the large tarps.

3.3.5 Portable feed bunks

Four portable feed bunks (Appendix D) of 4.87m long, 1.21m wide and 0.66 high were used in each feeding event. The bottom frame of the feeder was constructed with 10cm x 10cm pressure treated skids. Sheets of 18mm plywood were cut to size and fitted to make the floor. Rough spruce lumber 5cm x 30cm were nailed into 10cm x 10cm corner posts to form the walls. One 5cm x 10cm centre support was placed at the top of the wall to provide structural strength. Each feeder provided enough space to feed approximately 20 animals.

Feeders were placed in the centre of the large feed collection mats, so that wasted feed could be collected after the feeding event. Feeders were moved from one series mats to the next after the completion of each feeding event.

3.3.6 Electric fence

An electric fence was used to control animal movement and to prevent contamination of the unused experimental area. Prior to the start of the experiment, animals were trained to respect the electric fence. Once the experiment started, the electric fence was moved each morning to expose a new row of mats or feeders for the next feeding event.

After the completion of the entire experiment, the electric fence was moved to the starting point to prevent the animals from having access to the feeding area.

3.3.7 Jiffy bale unroller

A "Jiffy" bale unroller (Westward Manufacturing Ltd., Didsbury, Alberta, Canada) was mounted on the deck of a one tonne 4-wheel-drive pickup truck. The unit was not equipped with a scale, requiring that bales selected for the "unrolled" portion of the experiment were weighed at the storage area prior to loading. The Jiffy unroller was used to transport and unroll 510kg MBAH bales onto the snow for the four feeding events (Appendix E). It is impossible to measure the amount of feed distributed by this system thus the need to pre-weigh and select a proper weight bale so the entire package can be unrolled and the unit be empty prior to departure from the feeding area.

With the Jiffy bale unroller, the average windrow of hay was 1.5m wide, 0.12m high and 71m long when the entire bale was unrolled.

3.3.8 Duratech "2640 Balebuster" bale processor

A 125 horsepower Ford New Holland front wheel assist tractor TX125 (Burr Ridge, IL) pulled and provided mechanical power (power take off and hydraulic) to the Duratech (Jamestown, ND) 2640 "Balebuster" bale processor (Appendix E).
This unit carried bales to the feeding area and shredded forage into windrows either onto snow or into feedbunks.

With the bale processor, a round bale is placed in the bale chamber. When delivery starts, the bale is rotated by a chain conveyor in the chamber and flails on a driven shaft opposite the rotating bale cuts into the surface of the bale shredding off forage material. Centrifugal force created by the flails directs the shredded material onto the discharge pan prior to exiting the chopping chamber. Discharged feed is carried by air flow onto an adjustable deflector shield which redirects the forage material either onto the snow or into portable feed bunks.

The amount of feed delivered was measured by an electronic scale mounted on the bale processor. When the required amount of feed was delivered, the machine was disengaged. The average windrow produced when the bale processor was used had a height of 0.45m, width of 0.67m and length of 76m.

3.3.9 Pre-experiment preparation

3.3.9.1 Initial MBAH feed test results compared to Provincial averages

Prior to the start of the experiment, 25 bales of MBAH were sampled using a Star Quality forage sampler (Edmonton, Alberta) to obtain a representative sample. Average sample analysis results reported on a DM basis; crude protein 11.6%, calcium 0.5%, phosphorus 0.24%, magnesium 0.15%, sodium 0.02%, ADF 37.2% and NDF 67.6% (Table 3.3.9.1). These values were used to formulate rations for the bred heifers.

The average feed test results for the MBAH used in this feeding trial was within one standard deviation of the mean for average test results for moisture, protein, calcium, and phosphorus for mixed alfalfa grass hay as reported by Suleiman (1987).

3.3.9.2 Adaptation

Feed delivery during the pre-trial phase was carried out in an area adjacent to the experiment feeding area. The pre-trial phase allowed machinery operators to be trained in feed delivery procedures by adjusting travel speed and feed delivery rates to match the distances required to cover all four collection mats. The practice feeding events also allowed technicians to be trained in sampling methodologies and data collection procedures. It also allowed us to monitor cattle movement along the length of the feed windrow and their response to movement of the electric fence and determine if feeding behavior was affected by fence location.

3.4 Start of the experiment

The feeding experiments commenced on February 2, 2005 when a minimum of 15 cm of snow had accumulated on the mats. This snow made the tarps invisible and prevented the tarps from acting as an artificial feeding surface. The snow surface was the norm, and is typical for winter field feeding conditions.

3.4.1 Feeding rate

The 55 bred heifers in the feeding trial weighed an average of 521 kg. National Research Council (2000) recommends DMI to be 2% of BW. For the heifers, this amounts to 10.42 kg DM per head per day. Experimental protocols required that the feeding rate be maintained at 90% of the NRC recommendations or 1.8% of DM (10.42 kg x 0.9) or 9.39 kg DM per head per day.

The restricted feed intake was used to encourage the heifers to consume as much of the MBAH as possible. This ensures that the amount of feed waste is not due to overfeeding. For the 12 days of the experiment that the heifers experience feed restriction, free choice straw from the bedding pack was available. Actual DM delivery for all feeding events was 9.28kg/h/d, or 1.78% of BW.

3.4.2 Feed Delivery

Feed was delivered mid morning, between 9:30 and 11:00 am. Animals were not allowed access to the feeding area when the feed delivery machinery was present. Feed was placed on the snow over the mats in the feeding area or directly into the feed bunks (Appendix E). The feeding equipment was moved from the area immediately after the feed was delivered.

3.4.3 Initial sample and data collection

3.4.3.1 Feeding on snow

Prior to feed delivery, four collection mats identical in size to those placed on the ground in the fall were laid on top of the snow adjacent to and in line with the existing mats. MBAH dispensed by bale shredder or bale unroller on the second set of mats were collected, weighed (Mettler Toledo scale, 15 kg, model 0028/A III, Mississauga, Ontario, Canada) and returned to their original location. Returning the material to the second tarp location maintained a continuous distribution of material within the windrow and did not impact the feed waste distribution along the length of the windrow. The total weight of forage obtained from the second mat was used to measure the weight of feed delivered over the snow covered mats. With a uniform windrow of delivered feed, it was assumed that weight measured on the second set of mats would be very similar to the amount of feed placed over the snow-covered mats. To confirm this assumption, the length of feed windrow was also measured. The total weight of MBAH delivered, divided by the length of windrow, provided a weight of feed delivered per m of windrow. This value should be similar to the weights obtained from measurements for each mat.

Four representative feed samples were collected in 50L plastic tubs during each feed event. The tubs were placed immediately adjacent to the snow covered mats. It was assumed that feed quality and physical characteristics of the MBAH delivered adjacent to the collection mats would be very similar over a total distance of 4 to 5m. The collected material was used to determine the proportions of plant fractions (%) for the delivered feeds as well as nutrient composition of each fraction.

The amount of time required to travel from the feed storage area to the feeding area, feed delivery, and return travel time to the feed yard was recorded. This information was required to calculate the cost of feed delivery.

After the initial data were collected, the electric fence was moved approximately by 5m because of the distance between the next series of collection mats used for the next feeding date and to allow all animals' access to both sides of the feed windrows. The fence also prevented the animals from disturbing the feeding areas to be used later in the experiment.

3.4.3.2 Feeding into portable feed bunks

Four portable feedbunks of 4.87m in length, 1.21m wide and 0.66m high were placed on top of 4.57m x 7.62m mats after a minimum of 15cm of snow had accumulated. Representative samples of feed offered were collected in a 50L plastic tub placed into each feedbunk (Appendix D).

When the MBAH was delivered into the bunks, approximately 25% of the total weight was placed into each feeder.

3.4.4 Collection of delivered meadow brome alfalfa hay feed samples

Four representative samples from each feeding event were collected in 50L plastic tubs. When feeding on snow, the buckets were randomly placed in line with the delivery path of the equipment to collect feed as it was discharged from the bale processor. When feed was shredded into the portable troughs, one tub was placed inside of each portable feed bunk to collect samples.

Samples from the unrolled bales were collected out of a 0.5m x 0.5m section of the windrow material. During the collection of the four feed samples per feeding event from the unrolled hay, care was taken to handle the samples gently to minimize damage causing separation of the leaf from the stem.

3.4.4.1 Sample separation into fractions

All representative samples were weighed as received, (AND Electronic, bench "FG" balance digital scale, Tokyo, Japan) and dried at 60^{o} C forced air drying chambers, for 7 days. Dry weights were recorded.

Once dried, samples were separated into two fractions by particle size. To separate the long stem material from the finer leaf material, a hand sieve 0.66m square was constructed of 13mm plywood. Sides 100mm high were attached to the base to prevent loss of forage material during the separation. A 5 cm grid was made onto the plywood, and at the intersection points of the grid, an 18mm holes were drilled through the plywood (Appendix K, Figure 1).

When the MBAH was placed onto the sieve and the contents were shaken, the finer or smaller particles dropped through the holes into a collection bucket; this material was considered to be the "fines" fraction. The longer material that remained on top of the sieve was considered to be the “coarse” fraction and was placed into the second collection bucket (Appendix K, Figure 2).

After the sample was separated into fractions, the two fractions were weighed separately to determine the proportions of fine and coarse fractions present in the delivered hay.

3.4.4.2 Preparation of delivered feed samples for lab analysis

Sixteen samples from each of the three treatments (total of 48 samples) were collected during the four replications completed during the experiment. After the original samples were dried and separated into two fractions, the material from each fraction was ground through a 1mm diameter screen using a #10 Wiley Mill (Thomas Scientific, Swedesboro, NJ). The entire sample was ground, thoroughly mixed, and duplicate sub-samples taken. One sample was sent to Norwest Labs (Bodycote) in Lethbridge. Analyses conducted on each sample included; moisture (AOAC-935.29), crude protein (AOAC-988-.05), ADF (AOAC-973.18), NDF (F.A.P.–Method 5.1), Ca, P, K, Mg and Na (AOAC-985.01Feed test results were statistically analyzed by using the proc mixed procedure (SAS version 9.1, 2002).

3.5 Collection of wasted feed

The cows were allowed a minimum of 24 hours and a maximum of 20 days to consume delivered feed from daily feeding events. There was no way to exclude the cows from the previous days’ feeding area by electric fence or other means. It was observed that the cows did not return to the previous days feeding area to continue eating. Very cold weather solidified the snow, wasted feed and manure, making it very difficult for the cows to consume additional feed. Removal of the collection mats from the feeding area started the second week of the feeding trial.

Rainfall in late November 2004, froze the mats to the ground, making removal very difficult. Using pry bars, post hole bars, hammers, and shovels, it took 6 to 10 man hours to remove one mat (Appendix F). Some of the mats were not removed from the feeding area until spring thaw.

Each mat was collected separately. Snow, feces and wasted feed on the small collection mat was collected (Appendix G); and was loaded onto a 1/2 ton truck. The truck was then parked in a heated barn and the snow melted for 5 to 7 days.

Materials on the larger mat that was placed under a portable bunk feeder were collected in the same manner as the small mats. A 7.3m SWS flat deck trailer (Westlock, Alberta) was required to hold all the collected material from one mat (Appendix G). The trailer was parked in a heated barn and the snow melted for 10 to 12 days.

Collected samples were inspected daily. Feces and other contaminants were removed from the melting snow and wasted feed. Efforts were made to remove as much manure as possible while minimizing the removal of wasted feed. However, it is not possible to confirm that all manure was removed, or that wasted feed was not mixed into manure and lost when the manure was removed. All collected material was allowed to air dry down to 25 -30% moisture content in the barn environment.

3.5.1 Preparation of wasted feed samples

The air-dried wasted feed was placed into paper bags. A broom was used to remove any wasted feed particles caught in the mat fabric. Materials on each mat was identified by location and feed event. Samples in all bags were dried in forced-air ovens at 60^{o}C for 7d. Larger samples were mixed by hand during the drying process to ensure all material to be completely dried.

3.5.2 Separation of waste material samples into fractions

Individual wasted feed samples were separated into coarse and fine fractions using the same sieving techniques used to separate the fine and coarse material in the original samples collected from each daily feeding event. Refer to section 3.4.4.1 for the protocol.

3.5.3 Nutrient intake by average analysis or fraction calculation

Rations are traditionally balanced using DMI and average nutrient content as reported on feed test reports. The second method to determine the nutritive value of a feed is to separate the feed into two fractions by particle size and analyze each fraction separately for nutrient composition. Nutrient content of feeds were calculated by multiplying the proportional weight of each fraction by nutrient content obtained from the feed analysis.

The MBAH, was separated into two fractions; the fine material which was mainly leaves less and stem pieces less than 18mm in length and the coarser material over 18mm in length. Feed that was delivered either by Jiffy bale unroller or bale processor was analyzed for each fraction and compared to the original feed analysis results obtained from the representative sample analyzed prior to the start of the trial (Table 3.5.3).

3.5.4 Nutrient content of wasted feed

In this study, the wasted feed collected from each feeding event was a sub sample of the delivered feed. It was assumed that the nutrient density of respective fractions in the coarse and fine fractions was the same as the nutrient density of the respective fractions in the wasted feed. Thus, when the wasted feed was collected, it was separated into two fractions by particle size, and weighed separately. Total nutrient loss was calculated from the total amount of coarse and fine material collected as waste material multiplied by the nutrient content of the fraction.

3.5.5 Statistics

To obtain sufficient data for statistical analysis, samples were collected from four feeding events per treatment and four samples per each feeding event. The plot plan is illustrated in figure 4. Sixteen samples of coarse material and sixteen samples of fine material from each feeding system (on snow and into portable bunks) were collected and submitted for analysis.

The mixed procedure of SAS (SAS 9.1, 2002) was used in all analyses and difference among treatment means were tested using Pdiff. Statistical difference was declared at $P<0.05$.

3.6 Results and Discussion

3.6.1 Use of standardized feeding rates

Feeding rates were standardized at a calculated DM intake based on 1.8% of average BW of the animal group in the experiment. This feeding rate is 90% of the reported rate found in NRC for Beef Cattle (2000), thus based on average animal weight, the group was limit fed. Animals were allowed unlimited access to the delivered feed. Thus, only the restriction was the amount of feed delivered on a daily basis.

Three reasons for choosing a standardized rate were:

1) to allow for trial-to–trial comparisons by limit feeding to a standard amount.

2) to encourage the animals to eat as much forage as possible from the windrow or digging through the snow to consume additional feed. This slight feed restriction for a 16 day feeding trial was not expected to compromise animal performance or health status.

3) to prevent arguments that the animals were provided feed ad libitum, thus wasted feed cannot be attributed to overfeeding.

3.6.2 Collection of wasted MBAH

When collecting the wasted feed, it was noticed that the delivered feed was worked into the snow and distributed down the entire profile of the snow down to the collection mat. With the animals walking over the windrow of feed, the animal hooves were effective in mixing delivered feed into the snow.

The snow, manure, and wasted feed collected from a small (snow) collection mat weighed 452 kg (Appendix G). This large volume of snow required 5 to 7 days to melt when placed in a heated barn. The melting mixture of snow, wasted feed and extraneous material was checked daily. During these inspections, extraneous material that was visible, such as manure and pieces of wood, were removed as much as possible. When the manure was removed from the melting snow, some wasted feed particles were also discarded with the manure. It was not possible to determine how much feed was lost with the manure or how much manure remained with the sample.

3.6.3 Feed waste obtained with MBAH

The amount of wasted feed was significantly ($P<0.0001$) different among the unrolled hay fed on snow, shredded hay fed on snow, and shredded hay placed into a portable bunk feeder. Collected waste was 12.3, 19.2 and 0% of the total DM delivered respectively (Table 3.6.3).

3.6.4 Separation of wasted feed into fractions

The sieving techniques mentioned above in section 3.4.4.1 were used to separate the wasted feed into fractions. With the unrolled bales, delivered feed had 93.6% coarse and 6.4% fine material (Table 3.6.4a). The wasted feed contained 40.8% fines and 59.2% coarse material. The difference in fractions between delivered and wasted material was significant ($P<0.005$).

Feed shredded onto snow consisted of 18.9% fine material and 81.1% coarse material when delivered and 45.7% fine material and 54.3% coarse material in the wasted material (Table 3.6.4a). The differences between proportions of coarse and fine material between the delivered feed and collected wasted feed were significant ($P<0.005$). The amount of MBAH provided and wasted is summarized in Table 3.6.4b.

3.6.5 Impact on animal nutrition

From the feed test results analyzed by SAS, the nutrient concentration differences between the coarse and fine material were significant ($P<0.0001$).

For the unrolled bale system, the protein content of MBAH calculated from the fraction system was 10.9% at the time of delivery. When 9.28 kg of hay was fed to an animal, 1017g of protein was provided to each heifer calculate using the Cowbyte$ ration balancing program (Alberta Agriculture, 2003). The wasted feed was 12.3% of the total weight delivered on a DM basis. It was calculated that 237g of protein or 23.3% of the total protein delivered was found in the wasted feed. Only 780g of protein was consumed per animal. Crude protein loss was greater than the physical loss experienced. The nutrients lost in the wasted feed reduced the effective or consumed protein content in the ration from 10.9% to 8.4%. Nutrient losses for Ca, P, Mg, K, Na, ADF, and NDF were also greater than the physical amount of lost feed (Table 3.6.5a). Adjustments to input values for ration formulation based on feed waste are listed in Table 3.6.5b.

With the bale shredder system, the protein content of the delivered hay was 11.0%. Feed waste was 19.2% of the total feed delivered on a DM basis. By fraction evaluation, 219g of protein or 21.5% of the total delivered protein was found in the wasted feed. The animals consumed 798g of the 1017 grams supplied in the delivered feed. As with the bale unroller system, losses of Ca, and Mg, were higher than the percentage of feed waste. Physical losses are summarized in Table 3.6.5c. Adjustments to input values for ration formulation based on feed waste are listed in Table 3.6.5d.

There was 0% waste collected when MBAH was shredded into portable feeders. Once the feed was placed into the feeder, the cows did not waste the forage. There was no impact on feed quality or additional feed required to meet the nutritional requirements of the animals.

3.6.6 Visual appraisal of delivered MBAH

After the bales of hay were unrolled on the snow, it was noted that a majority of alfalfa leaves remained attached to the stem after delivery. The leaves of the meadow brome hay did not appear to be shattered off the stem post delivery.

Forage delivered by the bale processor was physically altered compared to the original baled forage. After delivery, the majority of alfalfa leaves were stripped off of the stems. Sections of leaf material from the grass species were broken off approximately half way between the tip of the leaf and where it was attached to the stem.

Some of the thinner stems from the top sections of the alfalfa and grass species were also broken off into shorter length pieces. These observations were consistent with hay processed onto the ground or fed into feed bunks.

3.6.7 Animal movement during the feeding events

After the heifers were allowed access to the unrolled hay, they started consuming the hay from one end of the windrow. One animal (the same heifer each day of the experiment) was observed to walk down the middle of the windrow which resulted in additional fine leaf material to be shattered from the stems, increasing the total amount of fine material present during the feeding event.

Heifers in the middle of the herd bunted each other for position along the windrow, causing additional mixing of forage material into the snow. Hoof action from the moving group resulted in the feed material being dispersed outward from the delivered width of 1.5m to feed waste scattered over a width of 3.05m.

When the MBAH was delivered onto snow by bale processor, the bred heifers exhibited the same behavior patterns as was observed in the unrolled treatment. The dominant heifer was present at the front of the feeding group, picking at the windrow, consuming feed as forward movement occurred. The remainder of the group followed, hooves tramping in both fine and coarse material into the snow. Animals milling about scattered the windrow material from a delivered with of 0.8m to a final width of 4m.

Processing MBAH into the four portable feeders resulted in animals initially jostling for position at the bunk, but no animals were displaced or retreated from their space at the feeder. Animals at the face of the feeder shifted position along the length of the feeder to make room when challenged for space. Each animal had 0.88m of bunk space available, more than the 0.76m recommended per head (Weisenburger, 1981).

With more than adequate space at the bunk, antagonistic behaviors defined as a behavior of an animal that resulted in the displacement of another from the feeder, were less common than if space was limited (Buskirk *et. al.,* 2003). During the observation periods in this experiment, no feed was pulled out of the feeder or tossed over the shoulder during eating events.

3.6.8 Differences in feed test results of MBAH by delivery system

Unrolled and shredded MBAH have significantly different (P<0.01) amounts of crude protein, Ca and Mg content due to treatment, material effect and treatment by material interaction (Table 3.6.8)

Hay crops are not completely uniform. There is a variation in the percentage of legume and grass hay present in different areas of the field. When the hay is cut and baled, there will be differences in plant maturity and concentration of each within the bale. These factors have some impact in nutrient uniformity within the bale, and the samples collected during feeding, but these differences were considered minor for these discussions.

Differences in crude protein, Ca and Mg content between the coarse and fine material were partially due to the type of material present in each fraction resulting from the feed delivery system used. The fine material from the unrolled delivery method was mainly alfalfa leaves. The unrolled coarse material contained alfalfa stems with some leaves attached, along with some grass hay. When MBAH was processed, the fine material contained fine stems and leaves from alfalfa plants along with some leaf material from the grasses. The coarse material consisted of alfalfa stems with few leaves intact and most of the grass plant.

The protein content from the processed fine material was 1.5% lower than the unrolled. The presence of alfalfa stems and leaf material from the grasses in the processed fine material diluted or reduced the overall protein content of the fraction sample. This observation is supported by Sheaffer *et. al*., (2000) who reported differences between stem and leaf protein content for alfalfa. Mowat *et. al.,* (1965) reported differences in protein content between stem and leaf material for timothy, bromegrass and orchardgrass.

Calcium and Mg content in alfalfa leaves is more concentrated than amounts in alfalfa stems (Sheaffer *et. al*., 2000). We found a 1% difference in Ca and a 0.12% difference in Mg which was attributed to the differences in nutrient concentration between alfalfa leaves and alfalfa stems or grass hay. The difference in nutrient concentrations is important because with both feeding systems, the fine fraction was the larger portion of the wasted feed.

Energy concentration differences between the fine and coarse material was calculated from the total amount of ADF in the ration (Mathison, 1984). The initial ration energy content was 2.67 and 2.73 Mcal DE/kg DM for the unrolled and processed MBAH respectively. When energy content in the wasted feed was accounted for, energy density of the ration that was consumed by the animals decreased to 2.33 and 2.20 Mcal DE/kg DM respectively for the unrolled and processed ration, representing a 12.8 and 19.3% loss in dietary energy.

3.6.9 Feed required when replacing nutrients contained in wasted feed

The amount of hay required to meet nutrient requirements of an animal based on feed test results can be different than the amount of hay to be fed when nutrient losses from feed waste are included in the calculation. In this experiment, each animal was to receive 1017g of protein when 9.28 kg of DM was fed. When feed was delivered with the unroller, protein contained in the waste material was 237g (Table 3.6.5a). This represents a 23.3% loss compared to the physical waste of 12.3% (Table 3.6.5b). Effective protein content of the hay was reduced from 11.0% when delivered to 8.4% consumed if the initial weight of hay delivered is used in the calculation (Table 3.6.5a). Feeding rate should be increased to 12.15kg DM/h/d for the animals to consume the 1017g of protein originally calculated. This increased total feed requirements by 29% compared to the 12.3% physical loss.

With the bale processor system, 9.28 kg of hay was delivered, same as the unrolled hay. Physical waste was higher at 19.2%. Of the 1017g of protein delivered, 219g or 21.5% was retained in the wasted feed (Table 3.6.5b). Effective protein of the hay was reduced from 11.0% when delivered to 8.6% consumed if the initial weight of the hay delivered is used in the calculation (Table 3.6.5c). Feeding rate would need to be increased to 11.86 kg DM/h/d for the animals to consume the 1017g of protein originally calculated. This increased total feed requirements by 28.7% compared to the 19.2% physical loss.

3.6.10 Implication of feed loss on animal nutrition

Calcium is the most abundant mineral in the body. It is required for maintenance and growth, lactation, bone strength and integrity (NRC Beef, 2000). Only 2% of the calcium found in the body is in extracellular fluids and soft tissues. Absorption of calcium is assumed to be 50% of total calcium intake (NRC Beef, 2000). Deficiency of calcium can cause rickets, reduce growth rates and impair skeletal development in young animals, and cause osteomalacia in adult animals (NRC Beef 2000). The minimum Ca : P ratio as calculated from NRC in a diet for replacement heifers is 1.3 : 1 in early stages of pregnancy and a 1.5 : 1 ratio in later stages of pregnancy. In commercial feeding operations, it is recommended that the ratio be maintained at a minimum of 1.67: 1, (Cattle Nutrition Course, 2001), but it is commonly recommended by industry feed nutritionists to maintain a 2 : 1 Ca: P ratio to have a safety margin in the rations (pers. comm. Vince Gabert, Viterra, Edmonton, Alberta, 2009).

In this experiment, the calcium phosphorus ratio narrowed from a 2.04 : 1 ratio at time of delivery to a 1.76 : 1 ratio for the unrolled hay and from a 1.77 : 1 at the time of delivery to a 1.66 : 1 for the shredded hay when the waste factor was included in the calculation. The reduced Ca : P ratio may increase the risk of milk fever in hypomagnesemic herds (Puls, 1988)

From the feed test results of the coarse and fine plant material, it was found that calcium and magnesium were more concentrated in the leaves, and potassium was in higher concentrations in the stem portion of the plants. The greater loss of fine material resulted in higher losses of calcium and magnesium from the ration than was the loss of potassium. A tetany ratio (Anonymous, Manitoba Agriculture, 2004) is calculated by dividing the total potassium in the ration by the sum of the amounts of calcium plus magnesium K/ (Ca + Mg) in milliequivalents. The delivered hay tetany ratio was 2.9:1. After feed losses were calculated and incorporating nutrient losses, the ratio increased to

3.43 : 1. When a tetany ratio exceeds 2.2 : 1 the animals on the ration are at greater risk of becoming downer cows (Walker, 2003; Merck Veterinary Manual, 2005).

The incidence of winter tetany, downer cows and milk fever in beef cows, has increased over the last 5 years (Anonymous, Manitoba Agriculture, 2004). It has also been noted by observation, that the downer cow problems are more frequent when cereal hays are fed using a bale processor (pers. comm. Bryan Doig, Saskatchewan Agriculture and Food, 2008). Taking into account the loss of calcium and magnesium from the fed hay due to feed waste, these observations are logical.

Low calcium levels in the ration during the last trimester of pregnancy and at the time of parturition can result in higher rates of uterine prolapse compared to animals fed a ration that is balanced for calcium and phosphorus (Risco *et. al.,* 1984). Cows that experienced a prolapse were more likely to be culled from the herd (Edegaard, 1977).

These additional costs of veterinary services to treat the prolapse, and costs of culling animals from the herd result in the need to raise additional replacement heifers to maintain herd size but further speculation is beyond the scope of this experiment.

3.7 Economic impact of feed waste

For the winters from 2002 to 2008, on average, Alberta cows were provided supplemental feed for 175 days per year (Kaliel, 2008). This was the standard time period used for all economic calculations. All feed cost calculations, waste, machinery and labour were also standardized to a herd size of 100 animals.

From January to June of 2005, average quality mixed alfalfa grass hay for beef cattle was valued at $0.066/kg in the Edmonton – Calgary corridor (Appendix H). With a feeding rate of 9.28kg DM or 10.98kg AF, the ration cost was $0.72 /h/d.

The focus of this study was to determine the amount of feed waste that occurs when a constant amount of feed was fed to the heifers using different feed delivery systems and location of feeding. The costs for salt, mineral, vitamins or other feed ingredients separate from the forage portion of the ration are not included in feed waste cost calculations.

3.7.1 Feed delivery costs

Factors used in economic calculations included; feed delivery costs, time of travel to and from the feeding area, processing time and total equipment time to feed the heifers.

In winter conditions, it is necessary to warm up equipment for 15 minutes prior to commencement of work. This cost is included in the equipment time calculations.

3.7.1.1 Tractor and bale processor

Total tractor time required for warm up, travel to and from the feeding area was 144 hours for the winter feeding period. With an operating cost of $91.00 per hour (Appendix B) for the tractor only, the working time generated an operating cost of $13,104.00.

The tractor and bale shredder operated 26.54 hours to process the forage onto snow. Operating cost for the tractor and processor is $108.11 per hour (Appendix B) or $2869.24 for the 175d winter feeding period.

Total cost to operate the tractor and bale shredder machinery cost for 175d was $15,973.24 or $91.27 per day or $0.91/h/d.

3.7.1.2 Jiffy bale unroller mounted on a 1 ton truck

Using the same factors mentioned above, the total time required to deliver and feed the heifers for the 175d was 153.63 hours. Operating costs for this unit was $63.90 per hour (Appendix B) or $9,817.36 for the winter. With 100 head in the group, equipment costs amounted to $0.56/h/d.

3.8 Value of wasted feed

With the Jiffy bale unroller, 12.9% of forage DM delivered was wasted. The heifers trampled in 1.14 kg/h/d DM or 1.41kg/h/d as fed of the MBAH into the snow. Feed losses were $0.093 per head per day or $5.11 per day for the group. Over the175d feeding period 26,475kg of hay was wasted. The value of the feed not consumed was $16.28/hd or $2448.00 for 100 heifers (Table 3.8)

With the bale processor, 19.22%, or 1.78kg/h/d DM of MBAH or 2.12 kg/h/d as fed was wasted. The value of the wasted feed was $0.14/h/d or $7.70 per day for the group. Over the 175d feeding period, 20,405kg of delivered hay was wasted, valued at $24.48/hd or $1,346.73 for the 55 heifers (Table 3.8).

Wasted feed is a direct cost to the cow-calf operation and a value can be placed on the loss. It is also possible to add indirect costs onto the total winter feed expense. To produce the hay that is wasted along with the additional feed to replace the lost nutrients in the wasted feed additional time and effort is required to make the extra hay needed to meet the total winter feed requirements, Costs such as seed, fertilizer, cutting and baling, hauling, and stacking can also be calculated. The opportunity costs of the additional land producing hay that is not sold onto the market or loss of revenue from not having the additional land to plant a cash crop is a more difficult value. Feed waste impacts the entire farming or ranching operation but to speculate and access these additional costs to the cow-calf operation are beyond the scope of this investigation.

3.9 Replacing protein loss with additional feed

Protein loss was 23.3% of the total supplied when the Jiffy bale unroller delivered the feed. The MBAH contained 11.0% protein (DM) when calculated from fraction results. The effective or consumed protein content of the delivered forage was reduced from 11.0% to 8.4% due to waste.

For the heifers to replace the 237g of lost protein when unrolled hay was fed, an additional 2.82kg DM or 3.35kg of hay as fed must delivered. This increases the total amount of forage offered to 12.10kg DM or 14.40kg of hay as fed per head per day. Feed costs would increase by $0.221/h/d. For the 175d winter feeding period, an additional 586kg of MBAH/hd or 58,625kg for the 175d feeding period is required to maintain the original protein consumption level at a cost of $38.67/hd or $3,867.00 for 100 heifers (Table 3.9).

Protein loss when MBAH was delivered by bale processor was 21.5% of total provided. Effective protein content of the hay was reduced from 11.0% to 8.6% when feed waste was considered. To replace the 219g of lost protein, an additional 2.55kg DM or a total of 11.83kg DM or 14.08kg of hay is required per head per day. This additional 2.55kg DM or 3.04kg of hay ad fed /h/d increases feed costs by $0.20/h/d. Over the winter feeding period, an additional 53,200kg of hay is required to feed the bred heifers at a cost of $ 35.11/hd or $3,511 for 100 heifers (Table 3.9).

3.10 Additional equipment costs to deliver forage

Additional feed is required to supply the recommended amount of protein in the original ration. For the unrolled MBAH, an additional 32,243kg of hay is needed to replace the lost protein, and for the processed hay, an additional 58,625kg of hay is required.

Using an average weight of 600kg for a MBAH bale, for the unrolled hay system, 98 additional bales are required. This requires 21.5 hours of equipment time valued at $1,377.9 to be added to the cost of feeding the heifers over 175 days. The additional equipment cost is $0.08/h/d.

With the bale processor system, 88 additional bales are required to replace the lost protein. This adds 22 hours of equipment time to feed the animals. The additional equipment cost is $2126.80 for a 175d feeding period or $0.123 cents/h/d.

3.11 Summary of feeding costs

The total costs of feeding the heifers including the cost of delivering the initial feed to the heifers, wasted feed and feed required to replace the protein lost in the wasted feed for the 100 bred heifers over a 175d feeding period is $ 276.67, $341.25 and $288.75 per head when feeding with a bale unroller onto snow, or a bale processor onto snow and a bale processor into portable bunks respectively (Table 3.11). Breakdown of winter feeding costs and total costs are summarized in Table 3.12.

3.12 Effect of hay price fluctuation on cost of feed waste

Hay prices can fluctuate dramatically from year to year and in some cases month to month. Hay price adjustments are related to weather related events, supply and demand, and producer perceptions. As the price of hay changes, the cost of the feed waste and hay required to replace the nutrients lost in the wasted feed will vary. Potential variation in hay costs are calculated in table 3.12.

3.13 Conclusions

In British Columbia, Alberta, Saskatchewan and Manitoba, there are 4,027,000 beef cows (Anonymous, Statistics Canada, 2009). Assuming that the average cow size was 590kg and that cows were fed hay at 13.5kg as fed on snow for 175 days, the amount of feed waste was calculated at 12.3% for unrolled hay and 19.2% for shredded hay on snow, the total feed loss for the winter per cow would be 290 and 454kg respectively. If 50% of the cows were fed hay on the snow for the entire 175 days and feed waste was eliminated for the 2,013,500 cows, financial savings for feed waste alone per annum would be $40 to $60 million if hay was valued at $66 /T. It is unrealistic to believe that feed waste would be completely eliminated; but if reduced, the economic return to cow calf producers would be very significant.

The larger variable cost incurred by cow calf operators was the cost of operating the equipment to feed the animals (Table 3.11). For the 100 heifers in the standard experimental group, total equipment costs were $0.56 per head per day for the bale unroller and $0.91 per head per day for the bale shredder when the total amount of hay delivered included the replacement hay needed for protein contained in the wasted feed. Feed waste contributed between $0.09 and $0.14/hd/d to winter feeding costs.

Equipment costs to deliver the hay to the feeding area were 6.2 and 6.5 times higher than the cost of the actual wasted feed for the bale unroller and bale processor respectively. Equipment operating costs had a larger impact on profitability than feed waste.

The economic importance of reducing feed waste increases with higher priced forage. At $0.066 per kg, the value of the wasted feed was $16.56 per head for the unrolled hay and $28.93 per head for the processed hay. If prices increased to $0.11 per kg, the value of wasted feed increased to $27.02 per head for the unrolled hay and $47.74 per head for the processed hay.

In 2005, net profit of cow calf operators in Alberta was $37.45 per calf (Kaliel, 2007). Reducing feed waste would increase the profitability of cow calf operations considerably in direct costs, let alone the associated costs of growing, harvesting, and feeding the forage when feed waste is present.

Table 3.3.9.1 Average nutrient content of meadow brome alfalfa hay *
by wet chemistry analysis

Nutrient content	*100% DM basis*
Crude Protein	11.6
Calcium	0.50
Phosphorus	0.24
Magnesium	0.15
Potassium	1.80
Sodium	0.02
ADF	37.2
NDF	67.6

* baled hay contained 84.5% DM

Table 3.5.3 Nutrient content in meadow brome alfalfa hay by two different calculation methods

Nutrient	Representative sample*	Unrolled **	Processed **
Crude Protein, %DM	11.6	10.95	11.01
Calcium, %DM	0.49	0.48	0.42
Phosphorus, %DM	0.24	0.24	0.24
Magnesium, %DM	0.15	0.15	0.15
Potassium, %DM	1.8	1.83	1.80
Sodium, % DM	0.02	0.02	0.02
ADF, %DM	37.19	37.43	34.90
NDF, %DM	67.59	66.05	68.78

* value from average feed analysis
* * values calculated by fraction nutrient content and proportional weight

Table 3.6.3 Amount of feed waste when feeding meadow brome alfalfa hay by percent

Treatment	Delivery system	% waste (DM basis)	SEM
MBAH - snow	Bale unrolled	12.31 [a]	2.41
MBAH – snow	Bale processor	19.22 [b]	2.41
MBAH – bunk	Bale processor	0.0 [c]	2.41

a, b, c, numbers with different column superscripts are significantly different ($P<0.0001$)

Table 3.6.4a Forage fraction breakdown of meadow brome alfalfa hay when fed by treatment at delivery and as wasted feed

Treatment	At Delivery			In Wasted Feed		
	Fines, %DM	Coarse, % DM	SEM	Fines, %DM	Coarse, % DM	SEM
In Bunk	18.92[a]	81.08[a]	1.16	0	0	
Shredded onto snow	18.92[a]	81.08[a]	1.16	45.77 [a]	54.23 [a]	1.79
Unrolled onto snow	6.38[b]	93.62[b]	1.16	40.83 [b]	59.17 [b]	1.79

a, b, numbers in columns with different superscripts are significantly different (P< 0.005)

Table 3.6.4b Amount of meadow brome alfalfa hay delivered, consumed and wasted by plant fraction when 9.28 kg DM was unrolled or shredded onto snow

Fraction	Feeding System	Kg fed DM basis	Kg waste DM Basis	DM Consumed	Loss as % of Kg fed
Coarse	Unrolled	8.69	0.675	8.015	7.76
Fine	Unrolled	0.59	0.465	0.125	78.81
Coarse	Shredded	7.524	0.967	6.557	12.8
Fine	Shredded	1.755	0.816	0.939	46.5

Table 3.6.5a Grams of nutrients delivered consumed and wasted* for meadow brome alfalfa hay unrolled on snow when 12.3% DM physical loss occurred

Nutrient	Delivered	Consumed	Waste	% Loss
Crude Protein, g DM	1017	780	237	23.3
Calcium, g DM	45	30	15	33.3
Phosphorus, g DM	22	17	5	22.7
Magnesium, g DM	14	11	3	21.4
Potassium, g DM	172	141	31	18.0
Sodium, g DM	2	1.6	0.4	20.0
ADF, g DM	3453	2826	627	18.1
NDF, g DM	6130	5011	1119	18.6

* Calculations done with the Cowbyte$ ® ration balancing program, Version 4.6.8, 2003, Alberta Agriculture and Rural Development.

Table 3.6.5b Reduction in nutrient concentration* of unrolled meadow brome alfalfa hay when 12.3% DM waste is experienced

Nutrient	Delivered Fraction value	Consumed value
Protein, %DM	11.0	8.40
Calcium, %DM	0.48	0.32
Phosphorus, %DM	0.23	0.18
Magnesium, %DM	0.15	0.12
Potassium, %DM	1.85	1.51
Sodium, %DM	0.02	0.017
ADF, %DM	37.44	30.5
NDF, %DM	66.05	53.9

* Calculations done with the Cowbyte$ ® ration balancing program, Version 4.6.8, 2003, Alberta Agriculture and Rural Development.

Table 3.6.5c Nutrients present* in 9.28kg DM delivered and 1.5kg wasted meadow brome alfalfa hay processed onto snow

Nutrient	Delivered	Consumed	Waste	% Loss
Crude Protein, g DM	1017	798	219	21.5
Calcium, g DM	39	29	10	25.6
Phosphorus, g DM	22	18	4	18.2
Magnesium, g DM	14	11	3	21.4
Potassium, g DM	168	137	31	18.4
Sodium, g DM	2	1.65	0.35	17.5
ADF, g DM	3246	2633	613	18.9
NDF, g DM	6394	5210	1184	18.5

* Calculations done with the Cowbyte$ ® ration balancing program, Version 4.6.8, 2003, Alberta Agriculture and Rural Development.

Table 3.6.5d Adjustment to nutrient quality* of meadow brome alfalfa hay when processed onto snow.

Nutrient	Delivered fraction value	Consumed value
Crude Protein, % DM	11.0	8.6
Calcium, % DM	0.42	0.31
Phosphorus, % DM	0.23	0.19
Magnesium, % DM	0.15	0.118
Potassium, % DM	1.82	1.47
Sodium, % DM	0.021	0.017
ADF, % DM	34.98	28.3
NDF, % DM	68.91	56.1

* Calculations done with the Cowbyte$ ® ration balancing program, Version 4.6.8, 2003, Alberta Agriculture and Rural Development.

Table 3.6.8 Nutrient content of meadow brome alfalfa hay fed to bred heifers in late pregnancy by processing method (T) and type of material (M)

Nutrient	Type of Material	Unrolled	Processed on snow	Processed into bunks	SEM	P Treatment (T)	P Material (M)	P (T x M)
CP	Coarse	10.53 [ah]	10.03 [a]	11.45 [a]	0.587	< 0.0001	< 0.0001	< 0.01
	Fine	17.31 [b]	14.97 [b]	15.85 [b]				
Ca	Coarse	0.42 [a]	0.32 [a]	0.51 [a]	0.077	< 0.0001	< 0.0001	< 0.0001
	Fine	1.44 [b]	0.83 [b]	1.13 [b]				
Mg	Coarse	0.14 [a]	0.14 [a]	0.16 [a]	0.012	< 0.001	< 0.0001	< 0.05
	Fine	0.26 [b]	0.21 [b]	0.24 [b]				
P	Coarse	0.23 [a]	0.22 [a]	0.23 [a]	0.047	NS	< 0.0001	NS
	Fine	0.29 [b]	0.29 [b]	0.29 [b]				
K	Coarse	1.87 [a]	1.88 [a]	1.79 [a]	0.071	NS	< 0.0001	NS
	Fine	1.56 [b]	1.54 [b]	1.59 [b]				
Na	Coarse	0.021 [a]	0.016 [a]	0.018 [a]	0.003	< 0.0005	< 0.0001	NS
	Fine	0.033 [b]	0.021 [b]	0.025 [b]				
ADF	Coarse	37.58 [a]	35.29 [a]	36.61 [a]	1.05	NS	< 0.0001	NS
	Fine	31.82 [b]	33.36 [b]	32.01 [b]				
NDF	Coarse	66.64 [a]	70.65 [a]	66.12 [a]	1.405	< 0.0001	< 0.0001	NS
	Fine	57.40 [b]	61.43 [b]	55.79 [b]				

a, b, difference between nutrient with different superscripts are different ($P<0.05$)

Table 3.8 Amount of wasted feed and associated costs* for the bale unroller and bale processor delivery systems

	Bale Unroller	Bale processor
Initial amount of hay fed	10.98 kg	10.98 kg
% waste	12.9	19.2
Kg feed waste AF	1.41	2.12
Value of wasted feed	$0.093	$ 0.14
Kg feed wasted over 175d	247	371
Value of wasted feed	$16.28	$ 24.48

* calculations are on a per head basis

Table 3.9 Additional feed costs* to replace protein contained in wasted feed

	Bale unroller	Bale shredder
Original protein content of hay, %DM	11	11
Grams of protein delivered	1017	1017
Grams of protein wasted	237	219
Protein loss (%)	23.3	21.5
Total physical waste	12.9	19.3
Kg hay AF required to replace lost protein	3.35	3.04
Additional feed cost to replace protein	$38.67	$35.11

* per head per day

Table 3.11 Total costs associated with feed waste, nutrient replacement and equipment costs* for the bale unroller and bale processor delivery systems

Costs	Jiffy Bale Unroller on snow	Bale processor on snow	Bale processor into portable feed bunk
Meadow brome alfalfa hay – original	$ 0.72	$ 0.72	$ 0.72
Equipment – original	$ 0.56	$ 0.91	$ 0.91
Additional Meadow brome alfalfa hay	$ 0.22	$ 0.20	$0.00
Additional Equipment costs	$ 0.08	$0.12	$0.00
Portable bunk feeder**	$0.00	$0.00	$0.016
Total cost /h/d.	$ 1.58	$ 1.95	$ 1.65
Cost /h/winter	$ 276.67	$ 341.25	$ 288.75

* per head per day
** initial cost of feeder $850.00. Expense amortized over 5 years.

Table 3.12 Cost of feed waste and nutrient replacement for 100 heifers over a 175 day feeding period calculated with different forage prices

Price of Forage /kg	Kg of wasted feed		Kg of feed to replace protein		Total cost $	
	CPS	RBS	CPS	RBS	CPS	RBS
Number of kg of feed	24,675	37,100	58,625	53,200		
$ / kg			Value of feed			
$0.066	$1,628	$2,448	$3,869	$3,511	$5,139	$5,959
$0.077	$1,899	$2,856	$4,514	$4,096	$6,413	$6,952
$0.088	$2,171	$3,264	$5,159	$4,681	$7,330	$7,945
$0.099	$2,442	$3,673	$5,803	$5,266	$8,245	$8,939
$0.110	$2,714	$4,081	$6,448	$5,852	$9,162	$9,933

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Chapter 4: Evaluating feed loss and nutritional impact on wintering beef cows fed two different physical forms of barley silage.

4.1 Introduction

Feed costs are one of the largest variable costs in beef production (Hughes, 1989; Kaliel, 2008). Feeding beef cows in winter is associated with substantial feed waste, which inflates total feed costs. The amount of waste is affected by the type of feeder used (Bell and Martz*,* 1976; Blasi *et al.,* 1993 Buskirk *et al.,* 2003), animal behavior (Albright, 1993), and how the forage is stored prior to the feeding period (Anderson *et. al*., 1981; Baxter *et al*., 1986; Brasche *et. al.,* 1988; Hand *et al.,* 1994).

Completed studies, (Bell and Martz, 1976; Buskirk, 2003; Landblom *et. al.,* 2007) all fed a single forage by a single delivery system to quantify the amount of winter feed waste. In a previous study (Yaremcio *et. al.,* unpublished data) we found that different feed delivery systems influence the amount of feed waste. Our results also showed that smaller feed particles, less than 18mm in diameter had a higher loss after feeding compared to the larger diameter particles. However, there are no published journal articles that show how particle size affects the quantity of feed waste.

4.2 Objectives

The first objective was to determine if the amount of feed waste was different between chopped pit silage (CPS) and round bale silage (RBS). The second objective was to evaluate the effect of particle size on the amount of feed waste. The third objective was to determine the impact of feed waste on the nutrition of beef cows and the economic impact feed waste has on wintering feed costs. The final objective was to evaluate the use of portable feed bunks as a method to reduce feed waste.

4.3 Materials and Methods

To make this experiment relevant to the cow calf sector, every attempt was made to employ common management practices used by producers throughout Alberta. Whole crop barley was harvested the last week of July, when, many producers cut annual forages for ensiling or greenfeed.

4.3.1 Experimental design

The treatments were arranged as a 2 x 2 factorial; silage type (bale or pit) and silage feeding method (bunk or snow). The treatment combinations were bale silage fed on snow (BSS), bale silage fed in bunk (BSB), pit silage fed on snow (PSS) and pit silage fed in the bunk (PSB). There were four replications and four blocks for each 2 x 2 combination. The blocking factor was week and was included as a random effect in the model. The response variables analyzed were proportions of coarse and fine material in the forage at the time of delivery and in the waste material, amount of feed waste, crude protein (AOAC-988-.05), Ca, P, Mg, K, Na (AOAC-985-.01), ADF (AOAC-973.18, and NDF (F. A. P. –Method 5.1). The mixed procedure of SAS (SAS 9.1, 2002), was used in all analysis. A Kenward-Roger option was used to adjust denominator degrees of freedom. The differences between least significant means was tested using Pdiff (SAS 9.1, 2003) and statistical significance declared at $P<0.05$.

4.3.2 Location

The feeding site was a 3 hectare perennial grass pasture (part of NW 13 40 27 W4) at the beef research unit located at the Agriculture and Agri-Food Canada Research Station in Lacombe, Alberta. This paddock was grazed over the summer and early fall.

The remaining forage was 5 cm or less in height at the end of the grazing season. This provided a fairly uniform surface for the collection mats to be placed upon.

4.3.3 Livestock and Feed

Twenty-two mature non-pregnant beef cows with an average weight of 736 kg were used in the experiment.

A cereal barley crop grown at the Research Station, and harvested at the late milk to early dough stage (Zadoks scale 7.5 to 8.5) (Zadoks *et. al.*, 1974) was stored as either RBS or CPS. For CPS the crop was chopped, packed into a horizontal silo and covered with 6mm white plastic sheets. The RBS were individually wrapped with 3 layers of white plastic within 12 hours of baling, and stored outdoors.

4.3.4 Feed waste collection mats

A geotextile fabric manufactured by Propex Geosynthetics (Chattanooga, TN.) was used to collect the wasted feed. The fabric is porous allowing liquids such as urine or melting snow to pass through but has sufficient strength to withstand mechanical damages from animal hoof activity (trampling) or equipment traveling over the fabric during feeding events.

Rolls of geotextile fabric (100m x 4.57m) were cut into 2.13m x 4.57m (small) or 7.62m x 4.57m (large) mats. The small mats were used during the snow feeding events; and larger mats were placed under each of the four portable feed bunks during CPS or RBS feeding events into portable feed bunks.

For each feed delivered (CPS or RBS) and location (on snow or into the four portable feed bunks), four rows containing of four mats each (n=16) were used in the experiment; with the plot design illustrated (Figures 5a and 5b). Total samples collected was 64.

Mats were placed on the ground prior to snowfall (Appendix C), stapled onto the ground to prevent movement by wind, place in rows of four providing four samples per feeding event. A space of 9m was kept between the feeding mats to allow collection of delivered feed samples from the CPS or RBS fed on snow. Each mat was identified by a numbered plastic ear tag placed in one corner of the fabric. Plastic flags attached to one end of a 50cm steel rod marked the location of the collection mats. One flag was placed in the centre of the small mat to indicate where the feed was to be delivered, while two flags were placed (one on each end) of the large mats indicating where the portable feed bunks were to be placed.

4.3.5 Portable feed bunks

Four portable feed bunks (Appendix D) measuring 4.87m long, 1.21m wide and 0.66m deep were used in each feeding event. Four feeding events each for the CPS and RBS were completed in the feeding experiment. During each feeding event one sample was collected from each feed bunk, providing four samples per feeding event for quality evaluation and statistical analysis.

The bottom frame of the feeder was constructed with 10cm x 10cm pressure treated skids. Sheets of 18mm plywood were cut to size and fitted to make the floor. Rough spruce lumber 5cm x 30cm were nailed into 10cm x 10cm corner posts to form the walls. One 5cm x 10cm centre support was placed at the top of the wall to provide structural strength. Each feeder provided sufficient bunk space to feed approximately 20 animals.

Feeders were placed in the centre of the large feed collection mats, so wasted feed could be collected after the feeding event. After the feeding event was completed the four feeders were moved by tractor to the next series of mats located under the snow.

4.3.6 Electric fence

An electric fence was used to control animal movement and to prevent contamination of the unused experimental area. Prior to the start of the experiment, animals were trained to respect the electric fence. Once the experiment started, the electric fence was moved each morning to expose a new row of mats or feeders for the next feeding event. After the entire experiment was completed, the electric fence was repositioned to the starting point to prevent the animals from having access to the feeding area.

4.3.7 Cattlelac silage truck

A Cattlelac (Red Deer, AB) feed mixer box (Model #520) mounted on an International (Warrenville, IL) single axle three ton truck was used to deliver CPS to the feeding area (Appendix E). The truck was equipped with a mounted electronic scale. Chopped silage was discharged from the mixer box via delivery chute. Amount and rate of silage discharge was controlled by a hydraulic discharge gate. The CPS was placed either on snow or in portable feed bunks. The mounted electronic scale and hydraulic chute allowed for accurate measurement and control of total silage delivery.

4.3.8 Duratech "2640 Balebuster" bale processor

A 125 horsepower Ford New Holland front wheel assist tractor TX125 (Burr Ridge, IL) pulled and provided mechanical power (power take off and hydraulic) to the Duratech (Jamestown, ND) 2640 "Balebuster" bale processor (Appendix E) which carried RBS to the feeding area and shredded forage into windrows either onto snow or into feedbunks. With the bale processor, forage is chopped when the round bale in the bale chamber is rotated by a conveyor chain and rotating flails on a driven shaft opposite the rotating bale cuts into the surface of the bale shredding off forage material. Centrifugal force created by the flails directs the shredded material onto the discharge pan prior to exiting the chopping chamber. Discharged feed is carried by air flow onto an adjustable deflector shield which redirects the forage material either onto the snow or into portable feed bunks.

The amount of feed delivered was measured by an electronic scale mounted on the bale processor. When the required amount of feed was delivered, the machine was disengaged.

4.3.9 Adaptation

Feed delivery during the 2d pre-trial phase was carried out in an area adjacent to the experiment feeding area. The pre-trial phase allowed machinery operators to refine feed delivery techniques by adjusting travel speed and feed delivery rates to match the distances required to cover all four collection mats. The practice feeding events allowed technicians to refine sampling methodologies and data collection procedures. It also allowed time to monitor cattle movement along the length of the feed windrow and observe their eating behavior when the electric fence was moved after feed delivery.

4.4 Start of the experiment

The feeding experiment commenced when a minimum of 15 cm of snow had accumulated on the mats. This snow layer prevented the tarps from acting as an artificial feeding surface, allowing the cows to consume more feed than would normally occur under typical winter field conditions. If feed was placed on the tarps without any snow, the amount of waste measured would be underestimated.

The experiment started on March 1, 2007 and required a total of 16 feeding days; four days for each of four treatments were required to complete the feeding trial.

4.4.1 Feeding rate for the mature cows

Average cow weight for the 22 non-pregnant mature cows in the trial was 736kg. The Nutrient Requirements of Beef Cattle, (NRC, 2000) recommends DMI be 2% of BW; which in this case is 14.72kg/h/d. Protocols for this experiment require that DMI be restricted by 10% or a maximum of 1.8% DM based on the body weight be provided daily. The restricted DMI would require 13.24kg/h/d (DM) of CPS and RBS be fed daily (Table 4.4.1a).

The RBS was delivered at 12.68 kg/h/d or 1.72% of BW on a DM basis compared to the target delivery of 13.24 kg/h/d. With 44.75% DM in the RBS, the total amount of silage as fed delivered to the 22 cows was 623 kg per day (Table 4.4.1b).

The CPS was delivered at 9.25 kg/h/d or 1.25% of BW on a DM basis compared to the target delivery of 13.25 kg/h/d (Table 4.4.1b). The 30.2% feed intake restriction was constant for all pit silage feeding events. The silage contained 70.3% moisture and an error in the moisture conversion calculation resulted in 685 kg of pit silage delivered daily rather that the required 994 kg.

The windrows of CPS delivered on the snow averaged 46m in length and the RBS windrows were 54m.

4.4.2 Collection of wasted CPS and RBS.

To reduce labour costs, the collection mats containing the wasted feed and snow were left in the feeding area until the spring. As the snow melted, manure and other debris were picked off the collection mats. Efforts were made to remove as much manure as possible while minimizing the removal of wasted feed. However, it is not possible to confirm that all manure was removed, and that wasted feed was not contaminated with manure.

The wasted feed was left on the mats to dry down in the field. All material was collected by replicate within feeding days and maintained as individual samples. Further drying in forced air ovens (60^{o} C) was required. After 7 days of drying, all samples were weighed and data recorded.

The portable feed bunks were checked approximately 24 hours after the previous feeding event.

4.4.3 Feed Delivery

Feed was delivered mid morning, between 9:30 and 11:00 am. Animals were excluded from the feeding area during feed delivery. Equipment delivering the feed crossed over the electric fence; placed the feed on the snow over the mats placed in the feeding area prior to snowfall, or directly into the feed bunks (Appendix E). The equipment departed from the area immediately after the feed was dispensed.

4.4.4 Initial sample and data collection

4.4.4.1 Feeding on snow

Prior to feed delivery, four collection mats identical in size to those placed on the ground in the fall were laid on top of the snow adjacent to and in line with the existing mats located under the snow. When CPS was delivered by the silage truck and RBS delivered by bale shredder, forage present on the second series of mats were collected, weighed (Mettler Toledo scale, 15 kg, model 0028/A III, Mississauga, Ontario, Canada) and material returned to their original location to maintain a constant concentration and distribution of feed in the windrow.

The total weight of forage obtained from the second mat provided a baseline measurement of feed delivered over the snow covered mats. With a uniform windrow of delivered feed, it was assumed that the delivered feed collected off the second mat and weighed would be very similar to the amount of feed delivered in the windrow over the snow covered mat. To confirm the uniformity of feed delivered per m of windrow, the total weight of feed placed in the windrow was divided by the length of the windrow to obtain an average weight of feed delivered per m of windrow. Assuming that if the windrow is uniform, the calculated weight of feed that the animals were offered was expected to be similar to the weights obtained from individual measurements from the second mats.

Representative feed samples were collected in 50L plastic tubs during each feeding event. Four tubs were placed immediately adjacent to each of the snow-covered mats. It was assumed that feed quality and physical characteristics of the feed delivered would be very similar over a total distance of 4 to 5m of windrow. The collected samples were used to establish proportions of plant fractions (%) for the delivered feeds as well as nutrient content of each fraction.

The time required traveling from the feed storage area to the feeding area, to deliver feed and to return to the feed yard were also recorded. This information was used to calculate the cost of feed delivery to the animals.

After the data and samples were collected, the electric fence was moved approximately 5 m to allow animal access to both sides of the windrows of delivered feed. The fence prevented the animals from disturbing the feeding areas to be used later in the experiment.

4.4.4.2 Feeding into portable feed bunks

The four portable feedbunks were placed on top of 4.57m x 7.62m mats after a minimum of 15 cm of snow was accumulated. A 50L plastic tub was placed into each of the four feedbunks prior to feed delivery and used to collect representative samples of the forage being fed (Appendix D).

When the CPS or RBS was delivered into the bunks, the machinery operators discharged approximately 25% of the total weight into each feeder to provide a constant amount of forage into each feeder. This helped to minimize the variation in the amount of waste measured at each replicate within a feeding event.

4.5 Collection of delivered CPS and RBS feed samples

Four representative samples (replicates) from each feed event were collected in 50L plastic tubs. When feeding on snow, the buckets were randomly placed in line with the delivery path of the equipment to catch feed as it was discharged from the bale processor or silage truck. With the portable bunk feeders, the tubs were placed in the central area of the feeders prior to delivery. Once the feed was delivered, tubs were removed from the windrows or feeders and samples of the CPS or RBS were taken for preparation for particle size and wet chemistry analysis. After samples were collected from the delivered feed, they were weighed as received, (AND Electronic, bench “FG” balance digital scale, Tokyo, Japan) and placed into forced air drying chambers, dried at 60 ^{o}C for 7 days.

4.5.1 Delivered CPS and RBS sample separation into fractions

4.5.1.1 High moisture round bale barley silage

Each RBS sample was separated into four fractions. A four step process was used to obtain coarse or long forage (stems), fine forage (mainly leaves), grain, and chaff fractions.

The initial step separated grain kernels from intact grain heads by processing the collected material through a home made grain de-bearding machine. The de-bearding machine has a 30 cm wide continuous textured rubber belt running over a series of four rollers to create a pressure point to thresh the grain out of the seed heads. Three of the four rollers are smooth, run on the inside or smooth side of the belt and are required to provide a framework to create a concave “L” shape when all four rollers are engaged (Appendix K, Figure 3). The fourth roller has a textured surface and runs against the outside or textured side of the running belt. When the textured roller was placed tight against the belt, the “L” shape was formed and friction between the belt and the rollers’ textured surfaces threshed the seed heads. When the material was released from the belt and roller, it was carried to the end of the belt and dropped off into one of two collection bins. A squirrel cage fan mounted below the belt directed a horizontal stream of air through the falling material. The heavier grain, along with some leaves, and chaff fell straight down into one collection bin. The lighter material comprising of long straw and leaf material was carried horizontally by the air flow and was deflected into a second collection bin.

To separate the long forage from the finer leaf material, a hand sieve 0.66 m x 0.66 m, constructed of 13 mm plywood with 100 mm sides was fabricated. A 5 cm grid was measured onto the plywood, and at the intersection points of the grid, an 18 mm hole was drilled through the plywood (Appendix J).

Long material greater than 18mm in length that remained on top of the sieve was considered coarse material, which consisted mainly of stems. The leaf material less than 18mm in length fell through the sieve, and was considered fine material. Each fraction was placed into separate bins for fine and coarse material.

The material captured in the first collection bin off of the de-bearder contained straw, leaves, grain and chaff which required further separation (Appendix L). The second step separated the grain and chaff from the long and short forage material. The entire content of the first collection bin was hand sieved over a series of metal grain dockage sieves. The top sieve, a 15/64 round hole sieve (Carter Day, Minneapolis, Mn) retained coarse material which was longer than 18mm in length on the top of the screen. The material off the top of the 15/64 sieve was added to the coarse material obtained from the de-bearding machine.

The second sieve, a #11 round hole sieve (Carter Day, Minneapolis, Mn) captured a vast majority of the fine forage material and allowed the grain and chaff to fall onto the third sieve. Material collected on the second metal sieve was placed into the fine material container.

The third sieve a 4/64 x ½ inch slotted sieve (Carter Day, Minneapolis, Mn) captured the grain and some fine forage material. The chaff and other very fine material fell through the sieve were captured on a solid flat pan. The material from the flat pan was considered the chaff fraction.

The grain fraction captured on the third sieve was contaminated with chaff and fine material. To clean the chaff and fine material out of the grain sample, a Carter Day International grain dockage separator, (model XT7, Minneapolis, Mn.) was used to separate the three fractions. The Carter Day utilizes gravity, wind and shaking motion to separate the mixture into grain, fine material and chaff fractions. The grain was collected separately by sample. The fine material was added to the fine material previously collected off the wooden sieve, and chaff obtained was added to the material collected off of the flat pan. Each fraction was weighed and results pooled by sample.

4.5.1.2 Chopped pit silage

The forage and grain portions of the CPS sample were separated using the grain de-bearder, metal grain hand sieves and the Carter Day machine. There was no long material greater than 18mm in length, so the wood sieve was not required.

The procedures used to separate the high RBS into fractions described in 4.5.1.1 were also used to separate the CPS into grain and forage fractions. The chaff portion of the material was combined with the forage. Dry weights for the grain and forage fractions were recorded.

4.5.2 Preparation of delivered feed samples for lab analysis

After the delivered feed samples were dried and separated into fractions, all materials were ground through a 1mm screen. Grain samples were processed using a

UDY Cyclone sample mill (Seedburo Equipment Co., Chicago IL, USA). The chaff, fine leaf material and long material were ground through a 1mm diameter screen using a #10 Wiley mill (Thomas Scientific, Swedesboro, NJ, USA). The entire sample was ground, thoroughly mixed, and two sub-samples were taken. One sample was sent to Norwest / Bodycote Laboratory, Lethbridge Alberta for analysis and the other sub-sample was kept in storage.

Grain samples were analyzed for concentrations of moisture, crude protein, Ca, P, Mg, K and Na. Additional ADF and NDF analyses along with the base package were conducted for the chaff, fine and long forage samples.

Nutrient analysis of the long material and fine material for the RBS was sent to Parkland laboratory (Red Deer, AB) instead of Bodycote/Norwest (Lethbridge, AB).

Comparisons between the average sample results and the fraction results must be adjusted to account for missing grain sample data. ADF and NDF values reported for barley grain (Marx *et. al.*, 2000) are 5.7% and 22.7% respectively. Therefore, the fraction values for barley grain were multiplied by the ADF and NDF as published by (Marx *et. al.*, 2000) and added to the laboratory results for the other fractions. The resulting ADF and NDF values should be closer to actual fibre levels present in the whole plant.

4.6 Collection of wasted feed

Removal of the wasted feed from the collection mats was delayed until mid-March. This reduced the amount of labour and time required to collect the samples, melt the snow, and dry down the samples prior to the preparation phase.

As warmer spring temperatures melted the snow, manure and other debris was picked out of the wasted feed daily until the wasted feed was dry enough for collection. Manure and debris was removed from the small and larger mats.

When the wasted feed was removed from the mat, material was moved by hand into paper bags. Straw brooms were used to dislodge any material caught in the fabric mat, ensuring complete collection of the wasted feed. All samples were placed in forced air drying ovens and dried at 60^{o} C for 7d. Dry weights were then recorded for all samples.

4.6.1 Separation of waste material into fractions

The same techniques used to separate the delivered feed samples of CPS and RBS were used to separate the CPS and RBS wasted feed material. Details are described in sections 4.5.1.1 and 4.5.1.2.

4.7 Nutrient intake by average analysis or fraction calculation

Rations are traditionally balanced using DMI and average nutrient content as reported on feed test reports. The second method to determine the nutritive value of a feed is to separate the feed into fractions by particle size or by physiological component and analyze each fraction separately for nutrient content. Nutrient content of feeds were calculated by multiplying the proportional weight of each fraction by nutrient content obtained from the feed analysis.

4.7.1 Nutrient content of wasted feed

From the discussion in 4.7, feed quality can be calculated from fraction weight multiplied by nutrient content. In this study, the wasted feed collected from each feeding event is a subsample of the delivered feed. It was assumed that the nutrient content in the wasted coarse, fine, grain and chaff fractions had similar nutrient density as the delivered feed samples. When the wasted feed was collected, it was separated into fractions, weighed and multiplied by the nutrient concentration of each fraction to calculate total nutrient loss.

4.8 Results and discussion

4.8.1 Amount of feed waste collected

Feed waste collected off of the tarps was 26.8% and 23.2% for the CPS and RBS respectively (Table 4.8.1). All wasted feed samples were collected in April after the snow had melted off the tarps.

4.8.2 Comparison of fraction and representative feed samples

Average nutrient content of the CPS samples was; 70.3% moisture, and on a DM basis; crude protein 12.25%, Ca 0.52%, P 0.29%, Mg 0.24% K 1.25% Na 0.51% ADF 34.1% and NDF5.7% (Table 4.8.2).

The average nutrient content of the RBS samples was; 55.25% moisture on a DM basis; crude protein 13.4%, Ca 0.55%, P 0.37%, Mg 0.17% Mg, K 2.13, Na 0.011%, ADF 31.2% and NDF 52.1% (Table 4.8.2).

The average chemical composition for the CPS and RBS used in this feeding trial was within one standard deviation of the mean for average test results for moisture, crude protein, Ca, and P for barley cereal silage as reported by Suleiman (1987).

4.8.3 Physical fractions in CPS and RBS

The CPS contained 83.2% forage fraction and 16.8% grain when delivered, and the waste material contained 89.9% forage and 10.1% grain (Table 4.8.3). The difference in fractions between the delivered and wasted feed was significant (*P*<0.01). Cows were able to sort through the snow to consume more of the grain and were not able to, or did not spend the effort to consume the forage fraction of the silage. This feed sorting behavior has been observed with dairy cows consuming more grain from a TMR than forage (DeVries *et. al.*, 2007).

The RBS fractions at time of delivery were 17.7% coarse material, 31.6% fine material, 5.5% chaff and 45.2% grain. In the waste material, 12.0% was coarse material, 40.0% fine material, 5.2% chaff and 42.8% grain. Differences in the relative amount of fractions delivered and collected waste was not significant (Table 4.8.3).

4.8.4 Nutrient content of feed fractions

Significant differences in crude protein, Ca, P, Mg and K concentrations (Table 4.8.4a) were observed between the grain and forage fractions of the CPS (P<0.01).

The crude protein content of the CPS grain and forage fractions placed into the bunk were significantly greater (P<0.001) than the silage protein placed on the snow. Similar differences were also observed for the P, Mg, and K content, but not for the Ca or Na content.

Feeding RBS in bunks or on snow did not show a significant difference in nutrient content in the forage fractions (long and short) delivered. There were significant differences (P<0.05) in the crude protein, Ca, P, K, Mg, ADF and NDF concentrations (Table 4.8.4b, 4.8.4c) between the long and short material as expected, but did not differ in nutrient concentrations between BSS and BSB.

The differences in nutrient concentration between plant fractions in CPS and RBS are consistent with results from a previous experiment (Khorasani *et. al.* 1997).

The grain and chaff fractions in the RBS were significantly different ($P<0.05$) in nutrient content ($P<0.05$) between the fractions. Feeding on snow resulted in significantly lower ($P<0.05$) crude protein, P, and K concentrations. We noted that there was a fine dust created when the RBS was shredded onto the snow. The dust drifted away from the windrow and we speculate that this dust contained high concentrations of crude protein, energy, Ca, P, Mg and K which may explain the difference in nutrient content between feed placed in the portable feeder and feed placed on the snow.

Crude protein, Ca, P and Mg levels were lower for the fraction results compared to the average results. This could be due to a number of factors. Sampling error, variability in the nutrient content of the plant material sampled due to differences in field fertility, crop maturity and yield could all influence the results.

In this experiment, two different laboratories were used for wet chemistry analysis for the long and short fractions from the RBS. Differences in laboratory procedures or technician methodologies may have influenced the results.

Comparisons between average test results and calculated feed values by fraction are summarized for CPS (Table 4.8.4d) and RBS (Table 4.8.4e). The difference in protein content for both the CPS and RBS is greater than one standard deviation compared to the average protein content of 11.9% (+/- 3.9%) for barley silage at samples tested in Alberta as summarized (Suleiman, 1987).

To mitigate the difference in protein content between average and the calculated fraction value, the fraction values were considered to be constant and used for all calculations in the experiment. The use of the fraction values was the only way to calculate the nutrient losses in the wasted feed. If the fraction nutrient values were low, then we may have underestimated the impact of feed waste on the nutrition of the cows.

4.8.5 Nutrient losses from wasted silage fed on snow

Feed waste reduced the overall quality of the CPS and RBS consumed by the cows. The initial ration calculated using Cowbyte$ (Alberta Agriculture, 2003) was different that the ration consumed. In this paper, discussion of nutrient loss will be limited to protein, but the principle of nutrient loss applies to all other nutrients and the values provided.

In this experiment, CPS delivery was limited to 1.28% of BW or 9.28kg DM basis compared to the experimental protocol of 1.8% DMI of BW or 13.24 kg. With feed delivery feed restricted by 29.9%, compared to the 10% required by experimental protocols. With the greater restriction in feed delivered, waste was 23.2% on a DM basis. There was no significant difference in feed waste compared to the RBS fed with a 10% intake restriction. By weighing back the wasted feed by fraction, we established that the cows were selective in their eating behaviour (Table 4.8.5a). The grain fraction in the CPS was 16.8% when delivered and significantly different at 10.1% of the wasted feed ($P<0.01$). More grain was consumed by weight and the forage fraction was either refused or the animals were not able to consume it out of the snow. Nutrients supplied, consumed and wasted are summarized in Table 4.8.5b.

The forage portion of the CPS contained more crude protein than the grain (10.14 vs. 7.06%; ($P<0.05$) (Table 4.8.4a). With the majority of the waste being the forage fraction, protein loss was 27.4% of the total supplied; greater than the total DM waste of 23.2%. The crude protein lost in the wasted feed would require 34% more silage to provide an equivalent amount of protein required in the original calculations. An additional 3.15 kg DM/h/d must be fed, for a total of 12.4kg DM /h/d.

Other nutrients were contained within the wasted feed. To reformulate rations, the nutrient content of the CPS must be reduced to reflect what is consumed rather than what was supplied (Table 4.8.5c).

RBS was delivered at 1.72% of BW on a DM basis, or 12.68 kg /h/d. Feed waste amounted to 26.8% of the DM delivered. The amount of waste between the CPS and RBS was not significantly different. The cows consumed greater amounts of grain and fine leaf material, and wasted the coarse and chaff material (Table 4.8.5a). With higher protein concentration in the grain and fine leaf material, and higher consumption of these fractions, protein lost in the wasted feed was 24.4% slightly less that the physical waste at 26.8%. Nutrients supplied, consumed and wasted are summarized (Table 4.8.5d).

There was 1651g of protein supplied when 12.68 kg DM was fed per animal. The wasted feed collected contained 404g of crude protein. To supply the original calculated amount of crude protein, an additional 3.43kg DM or a total of 16.1 kg DM of RBS. The crude protein lost in the wasted feed would require 27.0% more silage to provide an equivalent amount of protein required in the original calculations. Other nutrients were also wasted and replacement of the nutrients can calculated in the same manner as the protein. To reformulate the rations, the nutrient density in the RBS must be reduced to reflect what the animals actual consumed (Table 4.8.5e).

With the CPS fed at 1.28% of BW on a DM basis compared to the RBS which was delivered at 1.72% of BW on a DM basis, we speculate that the greater feeding restriction with the CPS resulted in a lower feed waste. If the experiment was to be repeated with the CPS fed at 1.8% of BW on a DM basis, we expect that the waste would increase. Farmers that have changed from feeding on snow to feeding in a portable bunk eliminated 35 to 40% feed waste (pers.comm. Grant Lastiwka, Alberta Agriculture and Rural Development, 2008).

4.8.6 Feed waste when feeding into portable bunk feeders

In all CPS and RBS bunk feeding events there was no feed present in the bunks the following morning. After the snow melted from around the bunks and manure removed from the large collection mats, there was no wasted feed to collect. Feed waste was 0%.

4.9 Animal behavior observations when CPS and RBS were fed on snow

Cows walked down the middle of the delivered windrows, trampling the CPS or RBS into the snow. A dominant cow led the group with the herd following behind. Animals pushed each other to gain better access to the feed. Once the cows travelled the entire length of the windrow, animals revisited areas of the windrow to consume additional feed.

When delivered, CPS formed a windrow 0.76m wide. Hoof action from the cows consuming the feed spread the silage to a width of 4.1m. The silage contained 16.8% grain by weight, providing 73g of grain /h/d. When the wasted feed was collected, only 10.1% of the wasted feed was grain resulting in a loss of 11.3g /h/d. The cows were very efficient locating the grain in the snow and consumed 86.6% of the grain available. The forage fraction of the CPS delivered was 10.5kg DM. Forage collected from the feed waste was 1.92 kg or 25% of the forage delivered (Table 4.8.5a).

The windrow formed by the RBS was 0.6m wide when delivered and expanded to 4.2m after the cows trampled the forage into the snow. Similar behavior was observed with the animals travelling down the length of the windrow as with the CPS. Percentage of RBS fractions delivered and present in the wasted feed are summarized in table 4.8.5a.

4.10 Round bale silage forage characteristics after delivery

The bale processor shattered most of the barley kernels out of the heads. Grain was found up to 10m away from the windrow (Appendix I). It was impossible to collect all grains lost and include them into the calculation for wasted feed.

The bale silage was physically altered by the processor. Grain, chaff, fine leaf material and long straw were identifiable in the windrow compared to the presence of whole plants in the bale when inspected prior to processing. The grain, chaff and leaf material settled onto the snow, in the centre of the windrow with the long straw forming a majority of the windrow volume.

4.11 Economics

4.11.1 Feed delivery costs

In Alberta, feeding cows over the winters of 2002 to 2008 required on average of 175 days of supplemental feeding (Kaliel 2008). This time frame will be the standardized winter feeding period for all calculations in this trial. Costs of providing salt, mineral, vitamins or other feed ingredients other than CPS or RBS are not included in the cost calculations for feed waste. All feed cost calculations, waste, machinery and labour were also standardized to a herd size of 100 animals.

From January to June 2007, annual crop barley silage containing 40% DM was valued at $0.031/kg AF in the Edmonton – Calgary corridor (Appendix H). With two silage products with different dry matter used in this experiment, value placed on the silage was converted to DM basis to make cost comparisons valid. Using 65% moisture as an industry standard for chopped silage, this converts $0.0775/kg DM. The CPS silage with a DM content of 29.7% is valued at $23.01/T AF and the RBS with a DM content of 44.75% is valued at 34.68/T AF. With a feeding rate of 9.25kg DM for CPS or 12.68kg DM of RBS, initial feed costs were $0.72 and $0.98 respectively per head per day. It was intended that the amount of DM fed with both feed types was to be standard across all treatments. As explained earlier, an error in DM calculations resulted in the DM delivery discrepancy.

4.11.1.1 Loading of pit silage into the delivery truck

A loader tractor filled the silage truck with pit silage prior to each feeding event. It required 10 minutes to load the required amount of silage. With an operating cost of $91.00 per hour (Appendix B) loading added $15.16 per day to the cost of delivering feed.

4.11.1.2 Silage delivery truck delivering pit silage onto snow

Prior to use of the silage truck, a 15 minute warm up period was required every morning of the winter feeding period. Operating cost for the truck is $105.67 per hour (Appendix D). The warm up period added $26.41 to the daily operating cost of the equipment.

The pit silage was stored approximately 1.2 km from the feeding area. Travel time to and from the silage pit was 10 minutes. Feed delivery onto the snow required an additional 8 minutes or 0.3 hours per day. This added $31.70 to the cost of daily feeding.

Total daily running time for the equipment including warm up and delivery was 0.55 hours per day. A daily equipment cost of $58.11 was incurred when delivering silage onto the snow. Cost of running the silage truck for the winter feeding period totaled $10,170.00 or $0.73 per head per day.

4.11.1.3 Silage truck delivering pit silage into portable feed bunks

When the truck was used to deliver pit silage into feed bunks the warm up period remained constant at 0.25 hours per day. With the small experimental feed bunks, the travel time remained constant at 10 minutes per day but delivery of feed required more attention to the operation of the equipment and time required to deliver the feed into four bunks required 18 minutes a day.

Total operating time for the truck for warm up and feeding was 0.71hours per day. Daily operating costs were $75.00 per day. Over the 175 day feeding period, total equipment costs incurred were $13,125.00 when placing the silage into the portable feed bunks.

4.11.2 Feeding high moisture round bale barley silage

4.11.2.1 Tractor and bale processor feeding onto snow

Prior to use of the tractor and bale shredder, a 15 minute warm up period was required each day. Operating cost for the tractor was $91.00 per hour (Appendix D). The warm up period added $22.75 to the daily operating cost of the equipment or $3891.25 for the winter feeding period.

The RBS was stored approximately 1 km from the feeding area. Travel time to and from the feed yard was 20 minutes or 0.33 hours. Moving feed from the storage area to the feeding area cost $30.03 per day.

Processing the required amount of feed onto the snow required 15 minutes or 0.25 hours of tractor and bale processor operating time. Operating the bale shredder as a separate piece of equipment is valued at $17.11 per hour. This increased the combined unit cost to $108.11 per hour (Appendix D). Cost of operating the combined unit is $27.02 per day. Total warm up, delivery and processing time for the equipment incur a cost a total of $79.80 per day or $13,965 for the winter. With 100 head in the group, equipment costs were $0.80 per head per day.

4.11.2.2 Tractor and bale processor feeding into portable feed bunks

When feeding the RBS into portable feed bunks, feed delivery time increased to 23 minutes per day or 0.38 hours, with an associated cost of $41.08 per day. Total equipment time including warm up, travel and delivery of feed into bunks was 0.93 hours per day valued at $93.86 per day or $16,425.50 for the winter. With 100 head in the group, equipment costs were $0.94 per head per day.

4.12 Value of CPS delivered and wasted

CPS was delivered to the cows at 9.25 kg DM or 31.13 kg as fed/h/d. With pit silage valued at $0.0775 per kg DM, original feed costs were $0.72/h/d. With 23.9% of the feed unconsumed by the animals, 2.2 kg of DM (7.5 kg AF) was wasted per head per day when CPS was fed on snow. Value of the wasted feed was $0.17/h/d. Total feed wasted by the group was 1314 kg as fed per head or 131 tonnies for the 175d feeding period.

4.13 Value of RBS delivered and wasted

RBS was fed at 12.68 kg DM or 28.33 kg as fed/h/d. Bale silage was valued at $0.0775/kg DM, original feed costs were $0.98/h/d. Wasted feed was 23.2% of the total delivered which amounted to 3.39kg DM or 7.58 kg AF/h/d, valued at $0.263/h/d. Total feed wasted over the 175d feeding period was 132 tonnes as fed per head.

4.14 Replacement of wasted protein in the pit silage ration

The original CPS ration was formulated to provide 1344 g of protein/h/d. With the restricted intake, total protein provided was 890g/h/d. Protein wasted from the 2.2 kg DM of CPS, resulted in 244g or 27.4% of protein retained in the wasted feed.

An additional 3.15kg DM or 10.6kg pit silage AF/hd/d over the 175d feeding period as fed is required to return the protein content in the consumed ration back to the initial calculated values. This contributes an additional cost of $0.24 per head per day or $42.72 per head over the winter feeding period. The increase in group feeding costs for the 100 cows was $4272. Total feed requirements increased by 185.5kg per animal for the 175d winter feeding period or 85.5 tonnes as fed for the group.

4.15 Protein replacement cost for bale silage

The RBS ration provided 1681g of protein when the ration was formulated. Unconsumed protein from the 2.93 kg DM resulted in 404g of protein loss from the 1681g supplied.

An additional 3.43kg DM or 7.66kg RBS as fed is required to return the protein content in the consumed ration back to the initial calculated values. This contributes an additional cost of $ 0.27/h/d, or $46.52/h for the winter feeding period or $4652 for the group over the winter. Additional feed requirements for the 175d winter feeding period were 1340kg/h as fed or 134 T as fed for the group.

4.16 Additional machinery costs

Supplemental feed is required to replace the lost protein in the ration. This requires additional operator and machinery time to transport and deliver the feed. An additional 185,500kg of CPS is required for the winter feeding period. This is equivalent to an additional 41.0 days of feeding at the original feeding rate. Delivery costs for CPS was $58.11 per day for the original amount of silage delivered and $15.16 per day to load the silage into the truck. Total cost to deliver the additional feed is $3,004.07 for the 175 day feeding period or $0.17 per head per day.

For the RBS, 134,05 T of additional feed is required to replace the protein lost in the wasted feed. This is equivalent to an additional 45.28 days of feeding. Delivery costs for the RBS was $79.80 per day. The cost of delivering and processing the additional bales increases winter equipment costs by $3613.34 for the winter or $0.20 per head per day.

4.17 Summary of silage feeding expenses

Winter feeding costs for the experiment are broken down to include equipment and labour, initial allocation of feed, and the associated costs of replacing protein levels in the ration to original calculated values. All calculations have been adjusted to a 100 cow herd to compare costs in Chapter 3. This expense will decrease as herd size increases. All costs are summarized in Table 4.17a.

The cost of silage can change from month to month depending on the severity of the winter that can increase daily feeding requirements, thus reducing the supply of forage in the local area. With changing silage prices, the cost of feeding the herd for the winter can change. Impact of price changes is provided in Table 4.17b.

4.18 Conclusions

Feeding long and short barley cereal silages on snow resulted in high DM losses and a reduction in ration quality. From average feed test results, the calculated ration appears to be nutritionally sound for lactating cows. When feed waste is factored in, the protein content of the consumed feed is not adequate to maintain cows in late pregnancy. Nutrient loss in the wasted feed could lead to reduced animal performance both in weight gain and reproductive performance and could create conditions that effect metabolic disorders due to the narrowing of the Ca : P ratio.

Equipment costs to transport and deliver feed to the wintering cows were greater than the value of the wasted feed. In times of narrow or negative margins for many cow-calf operators, reducing the cost of providing feed to the wintering cow will improve the viability of the operation.

The amount of feed waste measured in this experiment was a best case scenario. Bale processor flails shattered RBS grain heads, resulted in some grain landing 10m away from the windrow and collection tarps. This loss was not measurable. Restricting feed by measuring feed deliveries to 90% of recommended NRC values minimized waste. On many commercial operations, load cell scales are not present on the delivery equipment resulting in an estimated amount of feed to be delivered. Farmers tend to overfeed wintering cattle to provide a margin of safety and ensure the animals have enough feed to eat. This intentional overfeeding increases winter feed costs and the amount of feed that is wasted. Educating the producer to find ways to reduce costs; either by use of portable feed bunks or more accurate methods to weigh feed deliveries will improve profitability of cow calf operations.

Table 4.4.1a Calculated amount of chopped barley pit silage and round bale silage fed daily to 22 mature beef cows calculated at 90%* of NRC requirements

Number of animals	Animal size	Feed type	DM required kg/head	As fed Kg /head	As fed Kg / group
22	736 kg	Pit silage**	13.24	45.19	994
22	736 kg	Bale silage***	13.24	29.60	651

* 1.8% of BW on a DMI basis
** Pit silage DM content 29.3%
*** Bale silage DM content 44.75%

Table 4.4.1b Actual feed delivery rates for chopped pit silage and round bale silage for 22 non pregnant mature beef cows

Feed type	Required feeding rate	Actual feeding rate	% of body weight
Round bale silage	13.25 kg	12.68 kg	1.72
Chopped pit silage	12.25 kg	9.25 kg	1.25

Table 4.8.1 Amount of feed waste when feeding chopped pit silage or round bale silage by %

Treatment	**Delivery system**	**% waste (DM basis)**	**SEM**
CPS - snow	Silage truck	26.8 [a]	3.68
CPS – bunk	Silage truck	0.0 [b]	0.0
RBS – snow	Bale processor	23.2 [a]	4.08
CPS – bunk	Bale processor	0.0 [b]	0.0

a b in columns are significantly different (P<0.0001)

Table 4.8.2 Average feed test results for chopped pit barley silage and high moisture round bale barley silage taken prior to start of trial

Nutrient	Chopped pit silage	Round bale silage
Crude Protein, % DM	12.25	13.40
Calcium, % DM	0.52	0.55
Phosphorus, % DM	0.29	0.37
Magnesium, % DM	0.24	0.17
Potassium, % DM	1.45	2.13
Sodium, % DM	0.51	0.11
ADF, % DM	31.4	31.2
NDF, % DM	50.7	52.1

Duplicate samples of each feed type submitted for analysis.

Table 4.8.3 Fractions present as a % of total material present at time of feeding and as feed waste for chopped pit silage and round bale silage

Pit silage	Fraction	Fed on Snow	SEM	Fed in bunk	SEM
Delivered material	Forage	83.2^{a}	1.86	83.2^{a}	1.86
	Grain	16.8^{m}	1.86	16.8^{m}	1.86
Waste material	Forage	89.9^{b}	0.99	0.00	
	Grain	10.1^{n}	0.99	0.00	

Difference in fraction concentration between delivered and waste material was significantly different (P<0.01)

Bale silage	Fraction	Fed on snow	SEM	Fed in bunk	SEM
Delivered Material	Coarse	17.7^{d}	1.36	17.7^{d}	1.36
	Fine	31.6^{j}	1.36	31.6^{j}	1.36
	Chaff	5.5^{s}	1.36	5.5^{s}	1.36
	Grain	45.2^{x}	1.36	45.2^{x}	1.36
Waste Material	Coarse	12.0^{e} (▼32%)	3.32	0.0	
	Fine	40.0^{k} (▲27%)	3.32	0.0	
	Chaff	5.2^{t}	3.32	0.0	
	Grain	42.8^{y}	3.32	0.0	

Differences in fraction concentrations between delivered and waste material was not significantly different

a, b compares % of forage in chopped pit silage at time of delivery and waste collection

m, n compares % of grain in chopped pig silage at time of delivery and waste collection

d, e compares % of coarse material in round bale silage at time of delivery and waste collection

j, k compares % of fine material in round bale silage at time of delivery and waste collection

s, t compares % of Chaff in round bale silage at time of delivery and waste collection

x, y compares % of grain in round bale silage at time of delivery and waste collection

Table 4.8.4a Wet chemistry analysis for chopped pit silage by fraction (T) and location of feed placement (L)

Nutrient	Fraction	Snow	Bunk	SEM	T	L	T x L
CP	Forage [z]	10.14	11.85	0.746	<0.001	<0.001	<0.0068
	Grain [z]	7.06	11.03	0.746	<0.001	<0.001	<0.0068
Ca	Forage	0.48	0.50	0.008	N/S	<0.001	<0.0025
	Grain	0.18	0.15	0.008	N/S	<0.001	<0.0025
P	Forage	0.26	0.27	0.020	<0.001	<0.054	<0.001
	Grain	0.19	0.29	0.020	<0.001	<0.054	<0.001
Mg	Forage	0.21	0.23	0.005	<0.001	<0.001	N/S
	Grain	0.10	0.12	0.005	<0.001	<0.001	N/S
K	Forage	1.24	1.32	0.055	<0.0001	<0.0001	<0.049
	Grain	0.60	0.81	0.055	<0.0001	<0.0001	<0.049
Na	Forage	0.56	0.60	0.013	N/S	<0.0001	<0.0001
	Grain	0.24	0.17	0.013	N/S	<0.0001	<0.0001
ADF	Forage	35.60	36.73	0.628	<0.05	N/E	N/E
	Grain	--	--	--	--	N/E	N/E
NDF	Forage	58.60	57.70	0.699	N/S	N/E	N/E
	Grain	--	--	--	--	N/E	N/E

z – sample size = 32

N/S not significant at $P<0.05$

T = type of fraction; either forage or grain

L = location of feeding; either onto snow or into portable feed bunks

Table 4.8.4b Wet chemistry analysis for bale silage by type of fraction (T) and location of feeding (L)

Nutrient	Fraction	Snow	Bunk	SEM	T	L	T x L
CP	Long $_x$	10.15	10.07	0.56	N/S	<0.0001	N/S
	Short $_x$	17.05	16.37	0.56	N/S	<0.0001	N/S
Ca	Long	0.59	0.56	0.02	N/S	<0.0001	N/S
	Short	0.84	0.84	0.02	N/S	<0.0001	N/S
P	Long	0.53	0.50	0.04	N/S	<0.0001	N/S
	Short	0.89	0.84	0.04	N/S	<0.0001	N/S
Mg	Long	0.18	0.19	0.01	N/S	<0.001	N/S
	Short	0.28	0.30	0.01	N/S	<0.001	N/S
K	Long	2.47	2.03	0.16	N/S	<0.02	N/S
	Short	2.90	2.72	0.16	N/S	<0.02	N/S
Na	Long	0.13	0.11	0.03	N/S	N/S	N/S
	Short	0.16	0.21	0.03	N/S	N/S	N/S
ADF	Long	57.45	55.70	0.45	N/S	<0.0001	<0.01
	Short	45.60	46.20	0.45	N/S	<0.0001	<0.01
NDF	Long	74.17	74.55	0.93	N/S	<0.0001	N/S
	Short	56.42	58.72	0.93	N/S	<0.0001	N/S

x – sample size = 16

N/S not significant at P<0.05

T = type of fraction; either forage or grain

L = location of feeding; either onto snow or into portable feed bunks

Table 4.8.4c Wet chemistry test analysis for bale silage for chaff and grain fractions

Nutrient	Fraction	Snow	Bunk	SEM	T	M	T x M
Crude protein	Chaff y	11.20	13.68	0.616	<0.001	<0.001	<0.001
	Grain y	11.52	12.86	0.616	<0.001	<0.001	<0.001
Calcium	Chaff	0.60	0.57	0.017	N/S	<0.001	<0.001
	Grain	0.10	0.09	0.017	N/S	<0.001	<0.001
Phosphorus	Chaff	0.30	0.41	0.022	<0.001	<0.001	<0.0002
	Grain	0.34	0.37	0.022	<0.001	<0.001	<0.0002
Magnesium	Chaff	0.16	0.16	0.005	N/S	<0.001	N/S
	Grain	0.10	0.11	0.005	N/S	<0.001	N/S
Potassium	Chaff	2.06	2.32	0.082	<0.001	<0.0001	N/S
	Grain	1.03	1.23	0.082	<0.001	<0.0001	N/S
Sodium	Chaff	0.12	0.11	0.007	<0.001	<0.0001	N/S
	Grain	0.05	0.05	0.007	<0.001	<0.0001	N/S
ADF	Chaff	34.67	30.70	1.133	<0.04	<0.0001	<0.005
	Grain	--	--	--	N/E	N/E	N/E
NDF	Chaff	60.70	52.85	1.425	<0.0024	<0.0001	<0.001
	Grain	--	--	--	N/E	N/E	N/E

y – sample size = 32
N/E no data available to estimate significance

N/S not significant at P<0.05

Table 4.8.4d Nutrient content in chopped pit silage by average analysis and calculated by the fraction method*

Nutrient	Average sample	By fraction
Crude Protein, % DM	12.25	9.60
Calcium, % DM	0.52	0.44
Phosphorus, % DM	0.29	0.26
Magnesium, % DM	0.24	0.20
Potassium, % DM	1.45	1.18
Sodium, % DM	0.51	0.52
ADF, % DM**	31.40	26.82*
NDF, % DM**	50.70	34.88*

* Calculations done with the Cowbyte$ ® ration balancing program, Version 4.6.8, 2003, Alberta Agriculture and Rural Development.

** AD F and NDF analysis not completed on the grain portion of the fraction sample

Two samples submitted for analysis for the average sample results
Sixteen samples submitted for analysis for the fraction sample results

Table 4.8.4e Nutrient content of round bale barley silage by average analysis and calculated by fraction method*.

Nutrient	Average sample*	By fractions
Crude Protein, % DM	13.40	13.20
Calcium, % DM	0.55	0.45
Phosphorus, % DM	0.37	0.54
Magnesium, % DM	0.17	0.19
Potassium, % DM	2.13	1.92
Sodium, % DM	0.11	0.11
ADF, % DM**	31.20	26.29
NDF, % DM**	52.05	34.45

* Calculations done with the Cowbyte$ ® ration balancing program, Version 4.6.8, 2003, Alberta Agriculture and Rural Development.

** ADF and NDF analysis not completed on the grain portion of the fraction sample

Two samples submitted for analysis for the average sample results
Sixteen samples submitted for analysis for the fraction sample results

Table 4.8.5a Feeding rates and waste collected from feeding chopped pit silage and round bale silage to wintering beef cows

Feed type	Fraction	Feeding System	Kg fed DM basis	Kg waste DM Basis	DM Consumed	Loss as % of Kg fed
Pit silage	Forage	Truck	10.55	2.64	7.91	25.0
Pit silage	Grain	Truck	2.13	0.30	1.83	14.0
Round bale silage	Coarse	Processor	1.64	0.30	1.34	18.3
Round bale silage	Fine	Processor	2.92	1.00	1.92	34.2
Round bale silage	Grain	Processor	4.18	1.06	3.12	25.3
Round bale silage	Chaff	Processor	0.51	0.12	0.39	23.5

Table 4.8.5b Nutrients delivered and wasted for chopped pit silage delivered on snow.

Nutrient	Delivered	Consumed	Waste	% Loss
Protein, g DM	890	646	244	27.4
Calcium, g DM	41	29	12	29.2
Phosphorus, g DM	24	17	7	29.1
Magnesium, g DM	19	14	5	26.3
Potassium, g DM	110	80	30	27.2
Sodium, g DM	48	33	15	31.2
ADF, g DM**	2783	1977	806	28.9
NDF, g DM**	4407	3131	1276	28.9

* Calculations done with the Cowbyte$ ® ration balancing program, Version 4.6.8, 2003, Alberta Agriculture and Rural Development.

* * No ADF or NDF analysis completed on grain fraction

Table 4.8.5c Adjustment to nutrient quality* of chopped barley pit silage when waste is considered

Nutrient	Fraction value	Effective value
Protein, %DM	10.60	7.74
Calcium, %DM	0.44	0.32
Phosphorus, %DM	0.26	0.18
Magnesium, %DM	0.20	0.15
Potassium, %DM	1.19	0.86
Sodium, %DM	0.02	0.15
ADF, %DM	30.10	21.30
NDF, %DM	47.60	33.80

* Calculations done with the Cowbyte$ ® ration balancing program, Version 4.6.8, 2003, Alberta Agriculture and Rural Development.

Table 4.8.5d Nutrients delivered and wasted* for round bale barley silage delivered on to snow.

Nutrient	Delivered	Consumed	Waste	% Loss
Protein, g DM	1651	1277	404	24.4
Calcium, g DM	57	43	14	25.0
Phosphorus, g DM	69	52	17	24.6
Magnesium, g DM	22	16	6	27.2
Potassium, g DM	245	184	59	24.1
Sodium, g DM	14	11	3	21.4
ADF, g DM	3334	2546	788	23.6
NDF, g DM	4368	2320	1024	23.4

* Calculations done with the Cowbyte$ ® ration balancing program, Version 4.6.8, 2003, Alberta Agriculture and Rural Development.

Table 4.8.5e Nutrient content of processed round bale barley silage delivered and consumed by cows when waste is included *

Nutrient	Fraction value	Effective value
Protein, %DM	13.30	10.07
Calcium, %DM	0.44	0.33
Phosphorus, %DM	0.55	0.41
Magnesium, %DM	0.19	0.14
Potassium, %DM	1.92	1.45
Sodium, %DM	0.11	0.08
ADF, %DM**	26.29	20.1
NDF, %DM**	34.45	18.3

* Calculations done with the Cowbyte$ ® ration balancing program, Version 4.6.8, 2003, Alberta Agriculture and Rural Development.

** No ADF or NDF test completed for the grain portion of the bale silage

Table 4.17a Total costs per head per day associated with feed waste, nutrient replacement and equipment costs for different feeding systems feeding silage on snow.

Costs	Pit silage on snow	Pit silage into bunks	Bale silage on snow	Bale silage into portable feed bunk
Original feed cost	$ 0.72	$ 0.72	$ 0.98	$ 0.98
Initial Equipment cost	$ 0.73	$0.75	$ 0.80	$ 0.93
Additional feed cost	$ 0.17	$0.00	$ 0.26	$0.00
Additional Equipment costs	$ 0.17	$0.00	$0.20	$0.00
Portable bunk feeder*	$ 0	$0.016	$0.00	$0.016
Total cost /h/d.	$ 1.79	$ 1.49	$ 2.24	$ 1.93

* initial cost of feeder $850.00. Expense amortized over 5 years

Table 4.17b Calculated cost of wasted feed and additional forage required for nutrient replacement for 100 mature cows over a 175 day feeding period using different forage prices

Price of Forage /kg	Kg of wasted feed		Kg of feed to replace protein		Total cost $	
	CPS	RBS	CPS	RBS	CPS	RBS
Number of kg of feed	131,400	132,650	185,500	134,050		
$ / kg			Value of feed			
0.024	$ 3,154	$ 3,184	$ 4,452	$ 3,217	$ 7,606	$ 6,401
0.035	$ 4,599	$ 4,643	$ 6,493	$ 4,692	$11,091	$ 9,335
0.046	$ 6,044	$ 6,102	$ 8,533	$ 6,166	$14,577	$12,268
0.057	$ 7,490	$ 7,561	$10,574	$ 7,641	$18,064	$15,202
0.068	$ 8,935	$ 9,020	$12,614	$ 9,115	$21,549	$18,135

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Chapter 5: Conclusions and future research

5.1 Conclusions

The initial hypothesis speculated that the amount of winter feed waste can be affected by forage type provided to beef cows and the method used to deliver the feed to the feeding area. It was further hypothesized that feed waste has a direct effect on the nutrition of the animal and economic well being of the operation.

The first objective of this experiment was to establish the amount of feed that was wasted when delivered onto snow. Using three different feed types; MBAH, CPS and RBS and three delivery systems, we found that there was a delivery effect and a forage effect on the amount of total waste.

Our results indicate that delivery system had an impact on the amount of feed waste. When MBAH was fed at a constant rate, delivered by a Jiffy bale unroller or a bale processor, waste was significantly higher ($P<0.0001$) when the bale processor was used (12.3 vs. 19.2%) indicating that delivery systems impact feed waste.

To evaluate the effect of feed type on feed waste, a cereal barley crop was harvested on the same day either as CPS, stored in a sealed horizontal silo, or as RBS (whole plant material) and preserved as plastic wrapped individual round bales. Using the appropriate feeding systems, we determined that the length of forage particle; chopped vs. whole plant material processed through a bale processor did not have a significant impact on feed waste ($P>0.0001$) with 26.8% and 23.1% waste for pit silage and RBS respectively. A confounding factor in these results was that the feeding rates were 1.27% and 1.72% DM of average cow BW, with the pit silage having the higher feeding restriction.

The second objective was to determine the impact of feed waste on animal nutrition. Upon evaluation of the feeding program, nutrient loss from the ration or comparing what was provided to the animals to what they actually consumed, a larger nutrient loss occurred compared to the physical loss. With the feeds broken down into fractions for more accurate evaluation, a greater proportion of the leaf and fine stem material was lost in the snow compared to the coarser or longer material. Feed test results indicated that leaf material and fine stems are of high quality, and had a large impact on nutrient loss.

When MBAH was fed with a bale processor, total nutrient loss was greater than for the forage delivered by the Jiffy unroller. This contradicts bale manufacturer claims that overall feed quality is improved by processing the forage, and the ability to reduce feeding rates by 25 to 30% and still obtain the same nutrition program as feeding long hay.

When cows were fed CPS, they consumed a higher proportion of the grain delivered compared to forage material. This sorting phenomenon did not occur when RBS was fed. The cows were able to sort and select more grain out the snow when the grain and forage fractions were approximately the same size, but the sorting did not occur with the RBS where large differences in particle size were observed.

The last objective, to calculate the economic impact of feed loss on a cow calf operation found that the cost of feed loss and nutrient replacement over a 175d winter feeding program ranged from $53.15 to $93.27 in increased feed costs and $121 to $291 in equipment costs when standardized to 100 animals in the herd.

The use of experimental sized portable bunk feeders proved effective to eliminate feed waste and reduce the overall cost of feeding cows over winter.

Claims by bale processor manufacturing companies that feeding rates can be reduced by 30 to 35%, improve quality of the forage delivered by mechanical processing of the forage, reduce the amount of waste that occurs by reducing sorting and make winter feeding more economical by using a processor have been proven false by the research conducted.

5.2 Recommendations

Mechanization of winter feeding will not change. How farmers and ranchers use and manage the technology they use for feeding can be changed. Efforts to disseminate this information through scientific journal articles, popular press, extension meetings, and writing of factsheets and other extension materials is needed to disseminate the information gathered.

There are different feeding systems such as bale grazing, swath grazing and winter grazing of dormant perennial forages that have minimal equipment use and have additional benefits of higher nutrient retention from manure than if the cows were fed in drylot situations.

Integration of the information available from different feeding systems and a whole system approach is needed to evaluate the cost of feeding cows and finding a combination of methods to improve efficiencies in western Canada.

5.3 Future research

The two feeding trials have identified future research opportunities in this area of study. Some of the possibilities are:

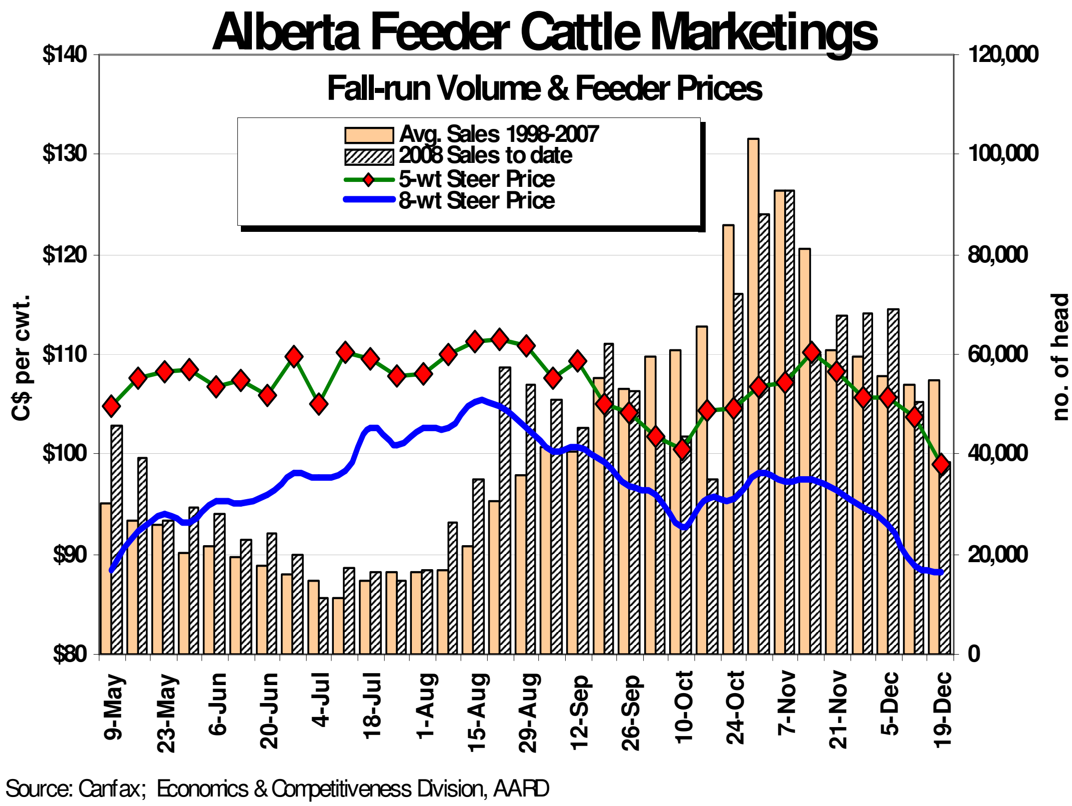
- Evaluate the value of the wasted feed as a nutrient source for the soil
- Conduct the pit silage and bale silage experiment again. Ensure that DM feeding rates are constant. Determine if the amount of feed waste for the pit silage was artificially low due to higher feed restriction.
- Evaluate the impact on microbial populations present in the rumen when forages are fed on snow. If feeding adjacent to previous used areas, there is a possibility of microbial contamination from fecal material or other debris present in the area.
- Continue work to develop a portable bunk feeder for use when feeding beef cows on extended range or cropland. Develop a prototype that can be used by commercial beef herds.
- Investigate the impact of feeding cereal grain along with chopped forage on snow.
- Conduct a feeding trial using higher quality forages such as a 60% alfalfa, 40% grass hay mixture to evaluate fine material loss and impact on animal nutrition.
- Evaluate feed losses when other feeding systems are used. For example bale grazing, or chaff grazing.

This project has created more questions than were answered. We now have a procedure to evaluate feed waste when cows are fed on snow, and a more accurate method of determining nutrient loss.

The results obtained will provide a platform for other researchers to evaluate how winter feeding programs are impacted by feed loss. Producers now have information to create a paradigm shift away from the common belief that 5 to 10% of the feed provided is wasted.

Appendix A:

Chart 1 Seasonal calf marketing in Alberta (Dobson, 2009)



2009

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Table I Average number of beef cows per farm in Canada from seven census periods from 1976 to 2006

Year	Canada	Alberta
1976	27	41
1981	31	46
1986	32	48
1991	38	54
1996	45	63
2001	53	74
2006	61	79

Survey 1

WINTER FEEDING PRACTICES QUESTIONNAIRE

Alberta Agriculture Food and Rural Development (AAFRD), Alberta Beef Producers, and the Western Forage Beef Group are involved in a research project to evaluate feeding losses that occur in cow–calf winter feeding programs. Winter feeding is a significant cost to the cow-calf operator and feeding losses only increase these costs. Components of this research project will involve field trials to evaluate the impact of bale processing on forage quality and feed intake, the impact of ground feeding versus bunk feeding forage on dry matter losses and the potential economic costs of feeding losses in the cow-calf sector.
Research results from this project will be available on Ropin' the Web (www.agric.gov.ab.ca) and the Alberta Beef Producers website (www.albertabeef.org).
This questionnaire will help researchers determine how cowherds are fed during the winter, and the length of the winter feeding period within Alberta.
Please support this project and help provide direction for future research by completing this questionnaire.

WINTERING BEEF COWS			
1a. Where is your feeding area? (forages only)		**1b. Where do you place the feed?**	
❑ in a pen	❑ other (specify)	❑ on the ground	❑ round bale feeder
❑ in a field		❑ in a feed bunk	❑ portable bunk feeder
1c. What percent of your feed do you think is lost using your feeding method?			
❑ 0 – 5%	❑ 5 – 10%	❑ 10 – 20%	❑ over 20%

2. Indicate on a percentage basis how you feed:		**3. What do you feed? (% of ration)**			
%	bale processor	%	straw	%	triticale silage
%	bales unrolled on ground (truck)	%	grass hay	%	perennial silage
%	bales unrolled on ground (tractor)	%	legume hay	%	oat greenfeed
%	round bale feeder	%	legume grass hay	%	triticale greenfeed
%	silage truck or wagon on ground	%	oat silage	%	barley greenfeed
%	silage truck or wagon into bunk or feeder	%	barley silage	%	other greenfeed
%	swath graze				
%	dormant season graze				
%	other (specify)				

4. Storage methods			
Bales:	❑ tarped	❑ shedded	❑ not covered

Chopped silage:	❑ bunker or pit	❑ pile		❑ tower silo	
- silage covering	❑ plastic	❑ other (specify)			❑ not covered
Bale silage:	❑ individually wrapped bales		❑ tube	❑ wrapped row	

5. If you use a bale processor, please indicate why. (Select up to 3 responses)	
❑ improve/increase feed intake	❑ to mix different types of feed
❑ increase digestibility of forage provided	❑ convenience and time saving
❑ reduce feed waste	❑ other (specify)

6. How many days did you provide baled feed or silage over the winter in **2003-04?** ________
How many animals did you feed in the winter of **2003-04?**
Bred heifers __________ Cows __________ Calves __________

How many days do you expect to provide baled feed or silage **this** winter **2004-05?** ________
How many animals are you feeding this winter **(2004-05)**?
Bred heifers __________ Cows __________ Calves __________

Postal code ____________ Zip Code __________

7. If you are using a bale processor, please complete the following questions:

a. How many days was a bale processor used to supply feed to the herd in **2003-04?** __________
b. Do you use the bale processor for bedding stock? Yes ______ No _______
c. Is grain placed on the processed feed? Yes ______ No ______
d. What percentage of your baled feed is fed with a bale processor?
Straw _____% Grass hay _____% Legume hay _____% Green feed _____%
Bale silage _____%

Please return by February 28, 2005 to:

Alberta Agriculture, Ag-Info Centre
Bag 600, Stettler, AB T0C 2L0 **OR**
Fax to: (403) 742-7527
Contact: Barry Yaremcio
1-866-882-7677
E-Mail: barry.yaremcio@gov.ab.ca

Version 7

Survey 2 Results from 2005 Feed Waste Survey

WINTERING BEEF COWS

	SURVEYS Total	%		
1a. Where is your feeding area?				
- in a pen	102	0.33		
- in a field	203	0.65		
- other (specify)	8	0.03		
1b. Where do you place the feed?				
- on the ground	168	0.49		
- in a feed bunk	53	0.15		
- round bale feeder	82	0.24		
- portable bunk feeder	43	0.12		
1c. % of feed lost in feeding method?				
0 – 5%	68	0.32		
5 – 10%	104	0.49		
10 – 20%	41	0.19		
over 20%	1	0.00		
2. Indicate on a % basis how you feed?		**Average**	**Range**	
- bale processor	6903	56	4	100
- bales unrolled on ground (truck)	1273	45	5	100
- bales unrolled on ground (tractor)	2826	50	3	100
- round bale feeder	3659	35	1	100
- silage truck or wagon on ground	1420	43	5	100
- silage truck or wagon into bunk or feeder	3501	59	10	100
- swath graze	1852	34	1	80
- dormant season graze	843	22	5	95
- other (specify)	876	46	1	100
3. What do you feed? (% of ration)				
- straw	3077	21	2	100
- grass hay	2578	32	5	100
- legume hay	1769	35	5	100
- legume grass hay	5339	48	0	100
- oat silage	1720	40	5	100
- barley silage	2979	49	5	95
- triticale silage	240	27	5	60
- perennial silage	515	34	5	100
- oat greenfeed	2510	34	5	100
- triticale greenfeed	100	33	20	50
- barley greenfeed	680	32	10	100
- other greenfeed	687	49	10	100

WINTERING BEEF COWS

	SURVEYS Total	%
4. Storage Methods		
Bales		
- tarped	13	0.06
- shedded	8	0.04
- not covered	199	0.90
Chopped Silage		
- bunker or pit	41	0.55
- pile	33	0.44
- tower silo	1	0.01
Silage covering		
- plastic	75	0.88
- other (specify)	4	0.05
- not covered	6	0.07
Bale Silage		
- individually wrapped bales	3	0.10
- tube	10	0.32
- wrapped row	18	0.58
5. Indicate why you use bale processor		
- improve/increase feed intake	57	0.16
- increase digestibility of forage provided	73	0.21
- reduce feed waste	80	0.23
- mix different types of feed	41	0.12
- convenience and time saving	73	0.21
- other (specify)	22	0.06

WINTERING BEEF COWS

	SURVEYS Total			
6. Feeding		**Average**	**Range**	
			Min	**Max**
Days provided baled feed or silage over winter 2003/04	39051	182	0	740
How many animals did you feed 2003/04				
- bred heifers	6358	36	1	270
- cows	31659	145	3	830
- calves	26094	147	0	2000
Days expect to provide baled feed or silage this winter (2004-05)	36378	172	20	300
How many animals feeding this winter?				
- bred heifers	5991	36	2	250
- cows	35299	160	2	1215
- calves	31429	165	4	3000
7. If using bale processor		**Average**	**Range**	
			Min	**Max**
Days used to supply feed to herd 2003/04	15954	139	0	365
Bale processor used for bedding stock		**%**		
- yes	132	0.92		
- no	11	0.08		
Is grain placed on the processed feed				
- yes	11	0.08		
- no	125	0.92		
% of your baled feed fed with bale processor		**Average**	**Range**	
- straw	7698	77	1	100
- grass hay	6156	73	2	100
- legume hay	5561	74	5	100
- green feed	4267	79	2	100
- bale silage	753	50	1	100

Table *II* Composition and *in vitro* disappearance of alfalfa herbage, dry hay and rained on hay (Collins, 1991)

Nutrient	Fresh plant	Dry Hay	Rained on hay	LSD (P>0.05)
Protein*, % DM	17.9 [a]	17.1 [b]	16.4 [c]	0.56
Ash, % DM	8.5 [a]	8.0 [b]	5.6 [c]	0.2
NDF, % DM	46.5 [a]	47.1 [a]	54.6 [b]	1.1
ADF, % DM	34.1 [a]	35.8 [b]	40.8 [c]	0.08
IVDMD, % DM **	61.8 [a]	61.3 [a]	56.8 [b]	1.3
NDF disappearance, % DM	49.0 [a]	45.5 [b]	45.5 [b]	1.6

* %N x 6.25 ** IVDMD after incubation for 48 hours

Table *III* Mean composition of forage from the outer 30 cm and inner core of large round bales after 4 or 9 months storage (Russell *et al.,* 1990)

	Harvest values	Outer 30 cm	Inner core
DM	84.9	80.3 [a]	85.9% [b]
IVDDM *	62.0	56.5 [a]	59.1 % [b]
ADF	33.5	39.8 [a]	38.2 % [b]
NDF	44.1	53.7 [a]	51.5 [b]
ADL	0.075	0.083 [a]	0.074 [b]
ADIN	6.6 g/kg N	9.6 g /kg N [a]	8.0 g /kg N [b]

a, b means with different superscripts within rows are significantly different *(P <0.01)*

* IVDMD after 48 hours of incubation

Table *IV* Feed refusal by rams consuming high density or low density bales (Russell *et al.,* 1990)

Binding Material	Bale Storage	Low Density bale	High Density bale
Net wrap	Ground	4.5 %	2.0 %
Net wrap	Rock	1.4 %	1.0 %
Twine	Ground	4.9 %	6.8 %
Twine	Rock	3.1 %	3.8 %

Table *V* Chemical properties of round bales after winter storage (Anderson *et al.,* 1981)

Cutting	Storage	CP, %DM	ADF, %DM	Unavailable CP, %DM	IVDMD, %DM*
First	Indoor	16.1 [a]	37.1 [a]	1.2 [a]	62.8 [a]
First	Outdoor	17.3 [a]	41.8 [b]	2.2 [b]	55.4 [b]
Second	Indoor	19.0 [a]	38.7 [a]	1.5 [a]	61.0 [a]
Second	Outdoor	19.2 [a]	42.2 [b]	2.1 [b]	53.9 [b]

A, b, means with different superscripts within cutting period are significantly different *($P < 0.05$)*

* IVDMD – no incubation period indicated.

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Table *VI* Hay quality by storage method and dry matter recovery (Brasche and Russell, 1988).

Hay	Length of storage	Location	ADF, %DM	NDF, %DM	IVDDM, % DM	DM recovery %
Alfafa Brome	Pre - storage		33.5	45.0	61.9	100
Alfafa Brome	20-26 weeks	Protected*	37.1	48.8	56.3	89.1
Alfafa Brome	20-26 weeks	Control**	38.5	50.9	54.4	78.5
Brome	Pre - storage		36.2	62.1	51.7	100
Brome	20-26 weeks	Protected*	37.3	64.9	51.7	102.0
Brome	20-26 weeks	Control**	39.0	66.0	50.6	93.0

* protected hay stored outdoors on tires, covered with plastic
** control hay stored outdoors on the ground with no plastic cover
*** 48 hour IVDMD value

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Table *VII* Forage quality parameters of alfalfa hay stem and leaf material under different storage conditions. (Werk *et al.,* 1998)

Bale storage location	Sample location	Covered by tarp	Leaf weight %	Leaf CP, %DM	Leaf NDF, % DM	Leaf CP, %DM	Leaf NDF, %DM	Leaf RFV	Stem CP, %DM	Stem NDF, %DM	Stem RFV
Ground	Surface	No	31.2	17.4	74.9	22.2	62.4	86	15.0	80.7	48
Ground	15 cm	no	37.3	21.8	60.7	26.6	48.3	116	16.0	72.7	58
Gravel	Surface	no	39.6	21.8	55.4	27.0	45.7	128	14.5	71.3	60
Gravel	15 cm	no	40.7	23.4	45.1	29.1	32.7	200	15.3	60.6	79
Gravel	Surface	yes	36.1	22.5	52.1	29.8	34.1	192	15.7	60.8	80
Gravel	15 cm	yes	32.6	22.8	47.2	29.6	30.4	220	17.2	55.8	91
LSD (0.05)			NS	1.6	6.2	2.6	3.9	24.0	NS	5.1	9.3

Requ ested aug 5, 2009

Table *VIII*: Websites with Feed Waste Information

Location	***Date***	***Website***
Alaska University, Fairbanks	June 23/08	http://www.uaf.edu/ces/publications/freepubs/FGV-00145.pdf
Arkansas University	June 23/08	http://www.uaf.edu/ces/publications/freepubs/FGV-00145.pdf
Auburn University, Alabama	June 20/08	http://www.aces.edu/timelyinfo/Ag&NatResEcon/2007/December/DAERS_07_16.pdf
California State University	June 23/08	http://ari.calstate.edu/
Clemson University South Carolina	June 23/08	http://www.clemson.edu/camm/Camm_d/Ch3/dch3a_04.pdf
Colorado State University	June 23/08	http://www.colostate.edu/Depts/CoopExt/Adams/sa/livestock.htm
Columbia University	June 25/08	http://www.biolbull.org/cgi/reprint/59/3/301.pdf
Dickinson Research Extension Center, Dickinson, North Dakota	June 20/08	http://www.ag.ndsu.nodak.edu/dickinso/research/2001/beef01e.htm
Florida University	June 23/08	http://edis.ifas.ufl.edu/AA203
Georgia University	June 20/08	http://pubs.caes.uga.edu/caespubs/pubcd/SB53.htm
Department of Rural Development Hokkaido National Agricultural Experiment Station Hitsujigaoka, Toyohira-ku, Sapporo, Hokkaido, 062 Japan	June 25/08	http://www.agnet.org/library/eb/407/
Idaho University	June 20/08	http://www.cnrhome.uidaho.edu/default.aspx?pid=74842
Illinois University	June 26/08	http://www.livestocktrail.uiuc.edu/beefnet/paperDisplay.cfm?ContentID=6154
Iowa State University	June 23/08	http://www.iowabeefcenter.org/content/cow-calf/2007/Managing%20feed%20needs.pdf
MSU Extension Service	June 20/08	http://msucares.com/livestock/beef/stocker_novdec2006.pdf
Kentucky University	June 20/08	http://www.ca.uky.edu/agc/news/2007/oct/reducehayloss.htm
Maryland University	June 25/08	http://extension.umd.edu/publications/PDFs/FS644.pdf
Michigan State University	June 20/08	http://beef.ans.msu.edu/Extension/Publications/Cattle_Call_Newsletter/ccJan06.pdf
Missouri University	June 20/08	http://extension.missouri.edu/xplor/agguides/crops/g04570.htm
Montana State	June 23/08	http://www.animalrangeextension.montana.edu/Articles/Beef/Main-Nutrition.htm

University		
Nebraska University, Lincoln	June 20/08	http://www.tein.net/~msufergus/Ag/livestock/management_to_minimize_hay_waste.htm
New South Wales (Department of Agriculture)	June 26/08	http://www.dpi.nsw.gov.au/agriculture/livestock/beef/equip/other/self-feeders
North Carolina State University	June 23/08	http://www.faqs.org/abstracts/Environmental-services-industry/Composting-animal-mortalities-in-North-Carolina-Wood-waste-study-provides-clues-to-recycling-success.html
North Dakota State University	June 23/08	http://beefmagazine.com/products/reduce_hay_feeding_cost/
Ohio Stat University	June 20/08	http://ohioline.osu.edu/b872/b872_5.html
Oklahoma State University	June 20/08	http://purduephil.wordpress.com/2007/10/31/effect-of-hay-feeding-methods-on-hay-waste-and-wintering-costs/
Oregon State University	June 25/08	http://ir.library.oregonstate.edu/dspace/bitstream/1957/4293/1/SR%20no.%20263_ocr.pdf
Saskatchewan Department of Agriculture	June 26/08	http://www.agriculture.gov.sk.ca/Beef_Cattle_Feeding_Systems
South Dakota State University	June 23/08	http://agbiopubs.sdstate.edu/articles/ExEx5041.pdf
Tennessee University	June 23/08	http://www.tennesseenutritionconference.org/pdf/Proceedings2007/Proceedings-Lane.pdf
Texas A & M University	June 23/08	http://forages.tamu.edu/PDF/scs2003-08.pdf
Utah State University	June 20/08	http://extension.usu.edu/files/publications/publication/AG504.pdf
Virginia State University	June 20/08	http://www.ext.vt.edu/news/periodicals/livestock/aps-03_02/aps-195.html

Table ***IX*** Protein and Fibre content of whole alfalfa and plant components (Sheaffer *et al.,* 2000)

Nutrient	Whole plant	LSD*	Stems	LSD*	Leaves	LSD*
ADF, %DM	33.0	9.6	50.5	4.0	17.0	4.5
NDF, %DM	39.1	12.2	59.8	6.0	20.4	5.0
CP, %DM	21.3	5.3	12.2	3.3	29.9	6.0
DE, Mcal/kg*	2.79	---	2.35	---	3.19	---

* LSD significant at (P>0.05)

** From Ruminant Feed Evaluation Unit equation, (Mathison et al., 1984)
$$DE = 3.617 - 0.025\ (\%ADF)$$

Table *X* Contribution of head, leaf and stem to total yield of cereal silages at harvest (Khorasani *et al.,* 1997)

Crop	Plant Component	% DM
Barley	Head *	48.9
Barley	Leaf	27.1
Barley	Stem	24.1
Oats	Head *	42.9
Oats	Leaf	26.1
Oats	Stem	31.0
Triticale	Head *	40.8
Triticale	Leaf	24.0
Triticale	Stem	35.2

* includes spike, grain and awns

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Table *XI* Nutrient content of barley plant components at full maturity (Suleiman, 1987)

Nutrients	Chaff	Straw	Grain
CP, %DM	6.25	5.4	12.3
ADF, %DM	42.8	44.4	n/a*
Calcium, %DM	0.52	0.43	0.08
Phosphorus, %DM	0.13	0.09	0.39
Magnesium, %DM	0.17	0.13	0.14

* no values available

Table *XII* Dry matter losses as a factor of storage technique and feed refusal as a % of dry matter at baling (Baxter *et. al.,* 1986)

Forage storage system	% Waste DM
Small square bales stored indoors	7.1 [a]
Large round bales stored indoors	15.5 [b]
Large round bales stored outdoors, covered	11.6 [b]
Large round bales stored outdoors on tires, no cover	26.0 [c]
Large round bales stored outdoors on ground, no cover	33.4 [d]

a, b, c, d, % waste with different superscripts are significantly different ($P>0.05$). SEM 0.49

Table *XIII* Feed consumed in g /d by ram lambs (Russell *et al,* 1990).

Binding material	Bale Density	Storage location	Intake g/d	Intake as % DMI by BW
Mesh	Low	Ground	626	2.7
Twine	Low	Ground	481	2.1
Mesh	Low	Rock	668	2.9
Twine	Low	Rock	612	2.8
Mesh	High	Ground	427	2.2
Twine	High	Ground	319	1.7
Mesh	High	Rock	470	2.4
Twine	High	Rock	377	2.0

Table *XIV* Average winter feeding period for Alberta and feed costs as a percent of total production costs (Kaliel, 2004; 2007)

Year	Average Days on Feed	Winter feed as % of total production costs
2000	179	32.0
2001	186	41.8
2002	181	44.3
2003	213	49.1
2004	162	35.2
2005	145	31.3
2006	160	33.4

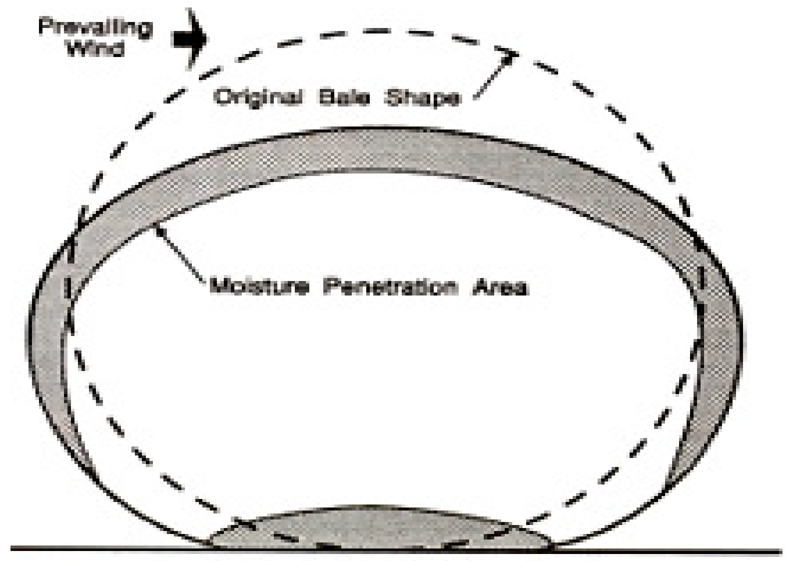
Table ***XV*** Net Savings from Processing Hay and Feeding in Bunks with three types of hay and three herd sizes. (Blasi *et. al.,* 1993)

Hay price per tonne	Number of cows in herd	Savings	Equipment adjustment *
$49.50	100	- $ 1,493.17	- $ 15,143.17
$49.50	200	- $ 494.34	- $ 14,144.34
$49.50	300	- $ 633.52	- $ 14,283.52
$55.00	100	- $ 1,126.76	- $ 14,776.76
$55.00	200	- $ 261.51	- $ 13,911.51
$55.00	300	$ 465.72	$ 13,184.28
$82.65	100	- $ 597.26	-$ 14,247.26
$82.65	200	$ 797.49	- $ 12,852.51
$82.65	300	$ 2,054.22	$ 11,595.78

* Net value to producer when tractor machinery operating costs of $91 per hour for 150 hours ($13,650.00) are included in calculations.

Used with permission from Dale Blasi, University of Kentucky. August 5, 2009

Figure *I* Shape transformation and moisture infiltration areas of round bales (Schott *et al.,* 1988)



Used with permission from Prairie Agricultural Research Institute, Research Update #673, published in June 1992. ISSN 1188-4770.

Figure *II* Depth of Spoilage and Bale diameter (Buckmaster, 1993)

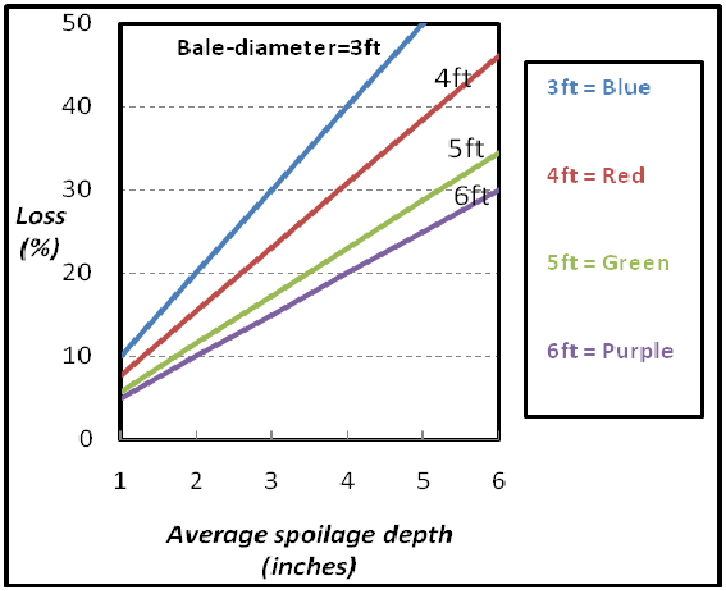
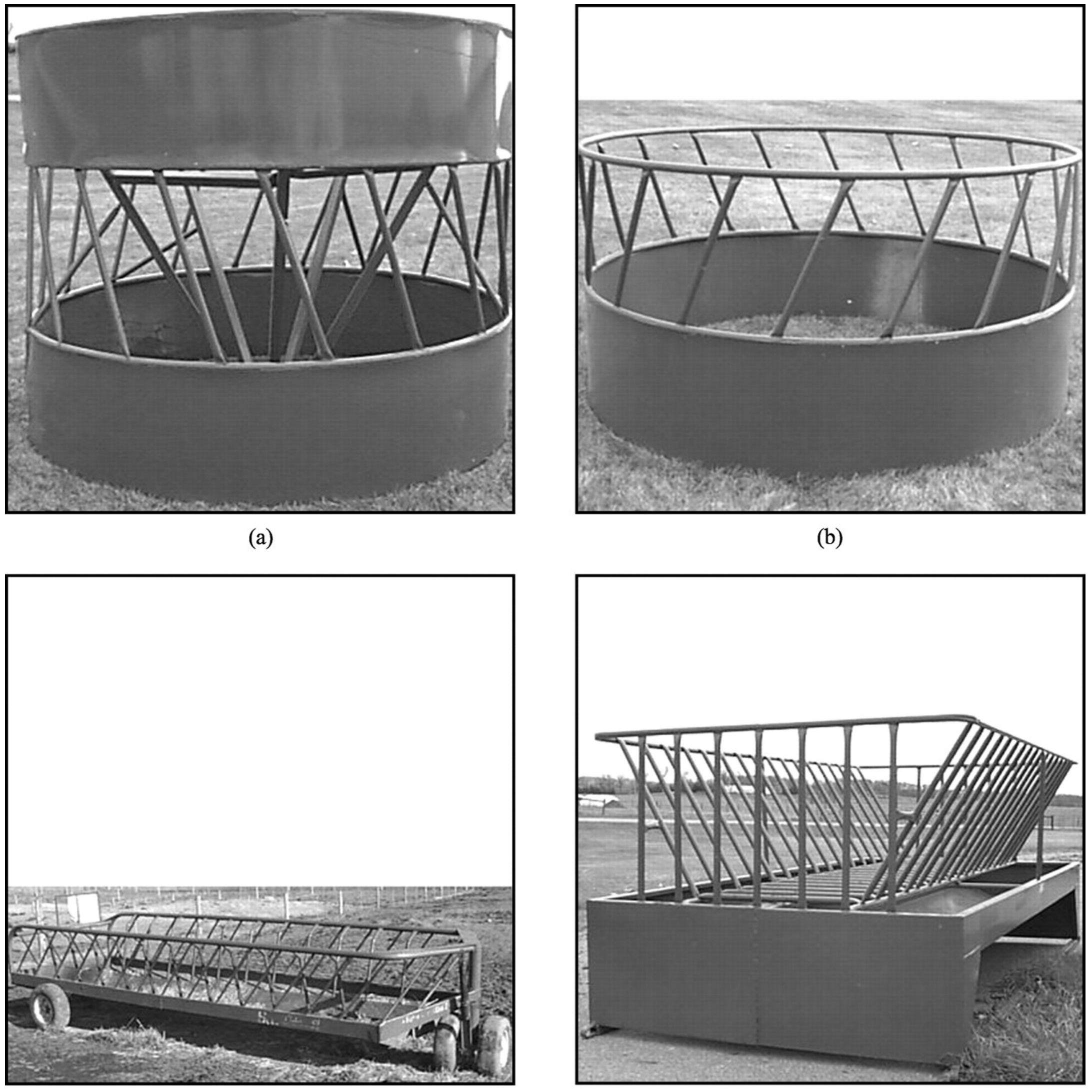


Figure *III* Feeder design and terminology (Buskirk et. el., 2002)



(a) (b) (c) (d)

Round bale feeder types: (a) ring, (b) cone, (c) trailer, and (d) cradle.

Used with permission from the Journal of Animal Science, 2007. 81:109-115.

Figure 4:

Plot plan for feeding Meadow Brome Alfalfa Hay onto snow or into portable feed bunks

Feeding on Snow	R_1	R_2	R_3	R_4
Day 1 Processed hay				
Day 2 Unrolled hay				
Day 3 Unrolled hay				
Day 4 Processed hay				
Day 5 Unrolled hay				
Day 6 Processed hay				
Day 7 Unrolled hay				
Day 8 Processed hay				

Feeding into Bunks	R_1	R_2	R_3	R_4
Day 9 Processed hay				
Day 10 Processed hay				
Day 11 Processed hay				
Day 12 Processed hay				

R – replicate samples collected during each feeding event (day)

Figure 5a

Plot plan for feeding pit silage or round bale silage onto snow

<u>Feeding on Snow</u>	R_1	R_2	R_3	R_4
Day 1 Pit silage				
Day 2 Bale silage				
Day 3 Bale silage				
Day 4 Pit silage				
Day 5 Bale silage				
Day 6 Pit silage				
Day 7 Pit silage				
Day 8 Bale silage				

R – replicate samples collected during each feeding event (day)

Figure 5b

Plot plan for feeding pit silage or round bale silage onto snow

<u>Feeding into bunks</u>	R_1	R_2	R_3	R_4
Day 1 Pit silage				
Day 2 Bale silage				
Day 3 Pit silage				
Day 4 Pit silage				
Day 5 Bale silage				
Day 6 Bale silage				
Day 7 Pit silage				
Day 8 Bale silage				

R – replicate samples collected during each feeding event (day)

Appendix B:

Equipment Cost Calculator (Alberta Agriculture and Rural Development)

http://www.agric.gov.ab.ca/app24/costcalculators/machinery/getmachimpls.jsp

Input Parameters: Bale processor and tractor

Data and assumptions	Tractor - Front Wheel Assist 125 HP	Bale processor Bale shredder
A Purchase price	$132000.00	$15900.00
B Planning period (years)	10	110
C Residual Value (at end of planning period)	$66000.00	$1590.00
D Annual hours of use (total use all operations)	400	80
E Fuel Usage (litres per hour)	21.00	
F Fuel Cost ($ per litres)	$1.10	
G Labour cost ($ per hour)	$20.00	
H Annual repair cost	$3960.00	$318.00
I Expected Return on Capital	8.77%	
J Marginal tax rate	0%	
K Rate of inflation	3.00%	
L CCA class rate	30%	20%
M Working width (ft)	0.00	0.00
N Working speed (mph)	5	5
O Field Efficiency (%)	70.00%	70.00%
P Acres per Hr	0.00	0.00

Ownership Costs	**Tractor - Front Wheel Assist 125 HP**	**Bale processor Bale shredder**	**Total**
1. Capital recovery ($ per year)	$12496.21	$892.70	
2. Insurance and housing ($ per year)	$1320.00	$159.00	
3. Total annual ownership costs	$13816.21	$1051.70	
4. Total ownership costs per hour	$34.54	$13.14	$47.68

Operating Costs

1. Fuel Cost	$9240.00		
2. Lubrication	$1386.00		
3. Repairs	$3960.00	$318.00	
4. Labour	$8000.00		
5. Total annual operating costs	$22586.00	$318.00	
6. Total annual operating costs per hour	$56.46	$3.97	$60.43

Total Costs

1. Total annual costs	$36402.21	$1369.70	
2. Total cost per hour	$91.00	$17.12	$108.11

Input Parameters: Jiffy bale unroller on a 1 T truck

Data and assumptions	**One tonne duel tire Farm truck with Jiffy unroller**
A Purchase price	$51500.00
B Planning period (years)	10
C Residual Value (at end of planning period)	$25750.00
D Annual hours of use (total use all operations)	400
E Fuel Usage (litres per hour)	21.00
F Fuel Cost ($ per litres)	$1.10
G Labour cost ($ per hour)	$20.00
H Annual repair cost	$1545.00
I Expected Return on Capital	8.77%
J Marginal tax rate	0%
K Rate of inflation	3.00%
L CCA class rate	30%
M Working width (ft)	0.00
N Working speed (mph)	5
O Field Efficiency (%)	70.00%
P Acres per Hr	0.00

Ownership Costs

1. Capital recovery ($ per year)	$4875.41	
2. Insurance and housing ($ per year)	$515.00	
3. Total annual ownership costs	$5390.41	
4. Total ownership costs per hour	$13.47	$13.47

Operating Costs

1. Fuel Cost	$9240.00	
2. Lubrication	$1386.00	
3. Repairs	$1545.00	
4. Labour	$8000.00	
5. Total annual operating costs	$20171.00	
6. Total annual operating costs per hour	$50.42	$50.42

Total Costs

1. Total annual costs	$25561.41	
2. Total cost per hour	$63.90	$63.89

Input Parameters: Silage Delivery truck

Data and assumptions	**Silage delivery truck**
A Purchase price	$138000.00
B Planning period (years)	10
C Residual Value (at end of planning period)	$69000.00
D Annual hours of use (total use all operations)	400
E Fuel Usage (litres per hour)	31.00
F Fuel Cost ($ per litres)	$1.10
G Labour cost ($ per hour)	$20.00
H Annual repair cost	$4140.00
I Expected Return on Capital	8.77%
J Marginal tax rate	0%
K Rate of inflation	3.00%
L CCA class rate	30%
M Working width (ft)	0.00
N Working speed (mph)	5
O Field Efficiency (%)	0.00%
P Acres per Hr	0.00

Ownership Costs	**Silage delivery truck**	**Total**
1. Capital recovery ($ per year)	$13064.22	
2. Insurance and housing ($ per year)	$1380.00	
3. Total annual ownership costs	$14444.22	
4. Total ownership costs per hour	$36.11	$36.11

Operating Costs

1. Fuel Cost	$13640.00	
2. Lubrication	$2046.00	
3. Repairs	$4140.00	
4. Labour	$8000.00	
5. Total annual operating costs	$27826.00	
6. Total annual operating costs per hour	$69.56	$69.56

Total Costs

1. Total annual costs	$42270.22	
2. Total cost per hour	$105.67	$105.67

Appendix C:

Placement of collection mats prior to snowfall.

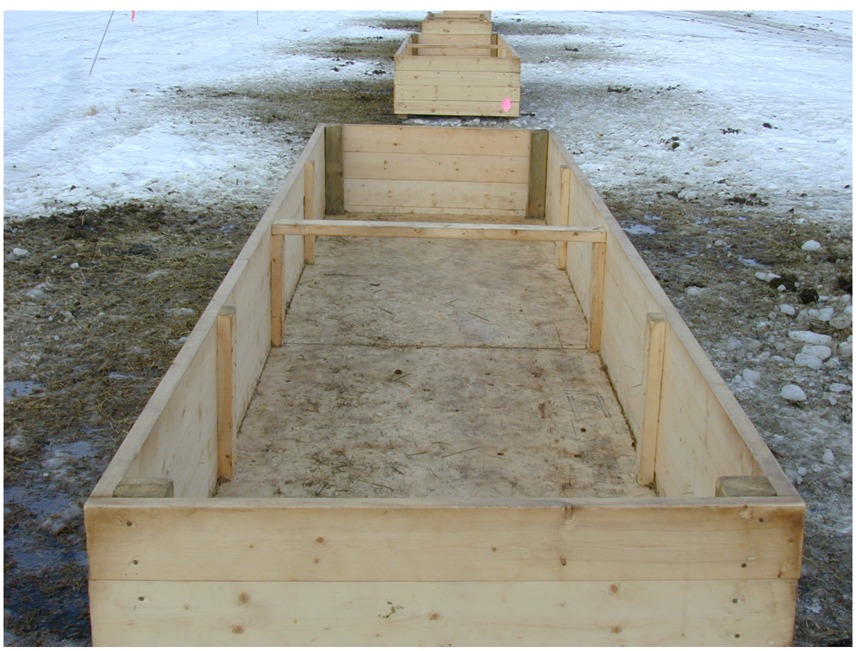
Selected winter feeding area after fall grazing

Placement of large tarps in rows (samples) for portable bunk feeders (one replicate)

One of four sample tarps is shown at the base of the picture. Replicate treatments progressing towards fence are shown towards the top of picture.

Appendix D:

Portable bunk feeders

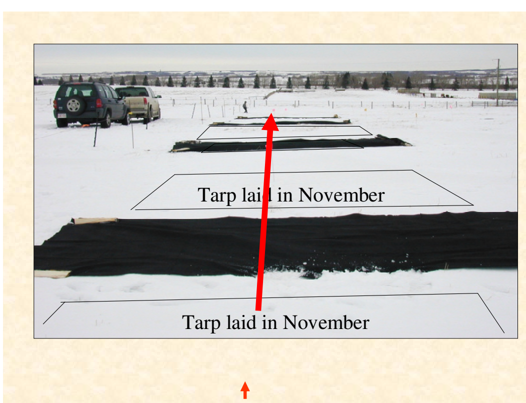


Appendix E:

Equipment used to deliver feeds:

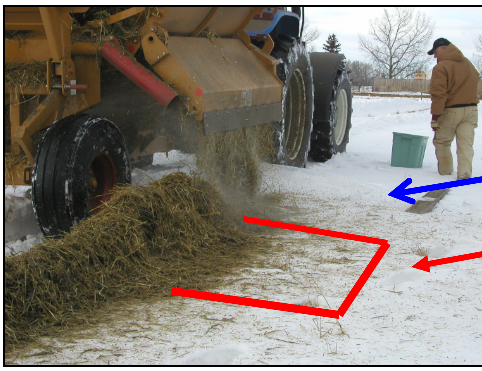
Bale unroller delivering bale of forage onto snow

Bale processor delivering bale forage into bunks



Feeding / collection tarps placed between waste collection mats.
Red arrow indicates direction of feed delivery.
Year one of feeding trial

Bale processor and tractor delivering bale forage onto snow



Feeding / quality collection tarp between waste mats under the snow (indicated in red). Year two of trial.

Pit silage delivery by truck mounted mixer box. (Picture taken after completion of the trial).

Appendix F:

Removal of a small collection mat after a feeding event

Locating edges of collection mat and lifting the mat off the frozen ground.

Wasted feed mixed in with the snow.

Area after mat was removed.

Appendix G:

Material collected from one small mat from a ground feeding event

Material collected from a large collection mat from under a portable feeder

Appendix H:

As Fed Cost of Forages – January to June 2005 (Jan – March)

http://www.afsc.ca/Default.aspx?cid=1-82-91-212

2005 Forage Central

Central	**Jan - Mar**	**Apr - Jun**	**Jul - Sept**	**Oct - Dec**
(Edm-Calg)	**$/lb**	**$/lb**	**$/lb**	**$/lb**
GRASS HAY				
1st Cut	0.029	0.030	0.029	0.029
2nd Cut	0.032	0.033	0.032	0.032
ALFALFA HAY				
1st Cut	0.033	0.032	0.030	0.030
2nd Cut	0.035	0.036	0.036	0.036
GREENFEED	0.020	0.025	0.022	0.022
SILAGE	22/ton	24/ton	22/ton	22/ton
(60% Moisture)	24/tonne	27/tonne	24/tonne	24/tonne
STRAW	0.013	0.015	0.016	.016

As fed Cost of forages – January to June 2007

http://www.afsc.ca/doc.aspx?id=1487

Central Edmonton- Calgary	January to March $/kg	April to June $/kg
Grass Hay		
1st cut	0.055	0.042
2nd cut	0.055	0.042
Alfalfa Hay		
1st cut	0.062	0.053
2nd cut	0.062	0.053
Greenfeed	0.048	0.046
Silage 60% moisture		
$/tonne	30	32
Straw	0.035	0.042

Appendix I:

Grain loss during delivery of HMRBS by bale processor

Appendix J:

Sieving of forage material

Figure 1 Plywood sieve with 18mm holes drilled on 5 cm centers.

Figure 2 Separation of coarse and fine material using the plywood sieve.

Appendix K

Separation of straw, fine leaves, grain, and chaff from Round bale silage.

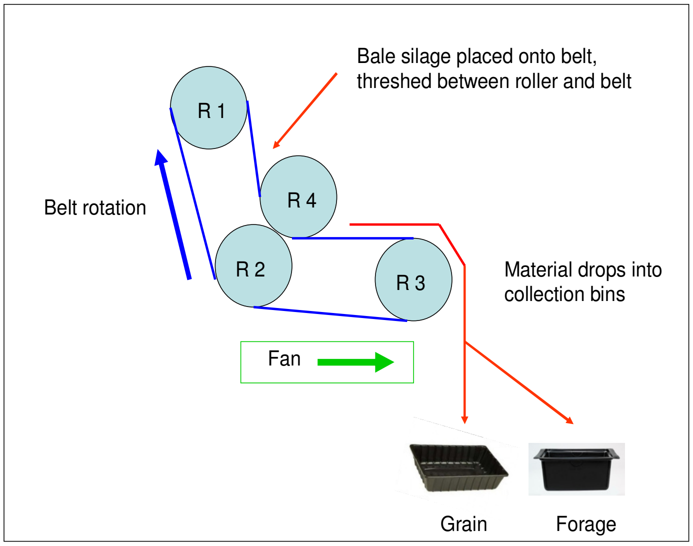


Figure 3 Schematic of grain de-bearding machine.

Appendix L:
Schematic of material separation for high moisture round bale silage