WINTER FEEDING BEEF CATTLE: A REVIEW ON BALE GRAZING IN THE NORTHERN GREAT PLAINS

A Paper
Submitted to the Graduate Faculty
of the
North Dakota State University
of Agriculture and Applied Science

By

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In Partial Fulfillment of the Requirements
for the Degree of
MASTER OF SCIENCE

Major Program:
Range Science

July 2019

Fargo, North Dakota

North Dakota State University
Graduate School

Title

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MASTER OF SCIENCE

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ABSTRACT

Bale grazing is a relatively unexplored winter feeding option for most beef cattle operations in the Northern Great Plains. Recently, several producers have been looking into using a bale grazing system for winter feeding due to the lower labor requirements and possible reduced cost. When bale grazing, it is not only important to ensure that cattle have adequate nutrition and protection from the winter climate, but also to analyze the positive impacts it has on the ranching ecosystem. Many positive environmental and economic changes have been seen from bale grazing including more efficient nutrient cycling, positive soil health impacts, increased forage production and quality, improved cattle nutrition, lowered production costs, and a decrease in nutrient waste, machinery use, and labor. Overall, bale grazing has shown to be a promising opportunity for ranchers to become more efficient and sustainable while winter feeding beef cattle on their operation.

ACKNOWLEDGEMENTS

I would like to thank Kevin Sedivec, Michael Undi, Stephanie Becker, the late Rodney Schmidt, the NDSU Range and Animal science departments, and all of the staff at the NDSU Central Grasslands Research Extension Center for their assistance throughout the bale grazing project. A special thanks to Kevin for taking me on as a graduate student and always being there to help with everything throughout my time at NDSU. Thank you for pushing me to take hold of opportunities as they arose, and always encouraging me to do my best. I appreciate your mentorship throughout the range industry! I would also like to thank all of the faculty in the NDSU the animal and range science departments that supported me in graduate school.

Thank you to Michael for taking lead on the bale grazing project and helping get the study all laid out and rolling. Your expertise in winter feeding helped me further my knowledge in all areas of animal science. Without Rodney and Stephanie's help, the bale grazing project would never have been able to run. Thank you for all of your help with getting the project set up, watering the cows throughout the winter, and collecting data. I know that the cows also appreciated your help when we had to walk them home after the huge blizzard that winter!

DEDICATION

This paper is dedicated to the late Rodney Schmidt. Rodney was the beef herdsman at the CGREC, my direct boss, and a special friend who is missed greatly by many. Rodney helped with everything throughout the bale grazing study, and was always there to laugh with when something would go wrong (which always would!). Throughout my time at the CGREC, Rodney became more like a dad to me than a boss, and he was always there to say a kind word or go the extra mile for anyone when they needed him. I think everyone that knew Rodney at the CGREC would say that it will never be the same without him working there.

Rodney was a great man of God, whom I sincerely admired; he always knew that at the end of the day it would all be alright if you had faith.

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LIST OF ABBREVIATIONS

ADG.....Average Daily Gain

BCS.....Body Condition Score

BW.....Body Weight

CP.....Crude Protein

CRP.....Conservation Reserve Program

DDGS.....Dried Distillers Grain with Solubles

DM.....Dry Matter

K.....Potassium

MBW.....Mature Body Weight

N.....Nitrogen

NGP.....Northern Great Plains

P.....Phosphorus

S.....Sulfur

INTRODUCTION AND LITERATURE REVIEW

Introduction

The largest cost for beef cattle operations throughout the Northern Great Plains (NGP) is winter feeding expenses. These expenses account for approximately 60% of all cow-calf production costs on an average ranch (Taylor and Field, 1995). Winter feeding expenses are high because most ranching operations in the NGP can only graze pasture for an average of six to seven months per year due to the adverse winter weather conditions in the northern regions of the United States and southcentral Canada. With large accumulations of snow during the winter season, it is nearly impossible to expect cattle to graze rangelands year-round as most of the dormant forage is snow covered and poor nutritional quality. In addition, dormant forage often lacks crude protein (<6% CP) and other essential nutrients (<50% TDN); these amounts do not meet the requirements for most gestating beef cattle (Figure 1; National Research Council, 2000).

Because dormant forage does not supply sufficient nutrition, some type of forage must be supplied to cattle for the remaining five to six months of the year. Forages can be fed in the form of hay, grain, silage, protein supplements, and several other types of alternative feed sources. The most common question that livestock producers often ask is “what is the cheapest and most efficient method to feed these forage sources to their cattle throughout the winter?” (Kelln et al., 2011). To answer this question researchers have explored various winter feeding methods, looking for the most efficient and cost-effective way to feed beef cattle during the winter season in the NGP.

There are numerous winter feeding methods that have been, and continue to be used on ranches throughout the NGP and other northern regions of the United States. Many new methods have been explored to find the best option that will fit a livestock producer’s operation. The

traditional methods include pen or pasture feeding forage such as the traditional unrolling of hay bales directly on grasslands or fields, or using a bale processor to spread hay on pasture. The most commonly used winter feeding method is feeding hay in feeders or a mixed ration in a dry lot setting where livestock are often exposed to harsh winter environments (Asem-Hiablie et al., 2016). There are also alternative methods such as lengthening the grazing season on rangeland pastures, grazing corn stalks or cover crop fields, swath grazing hay windrows, and bale grazing. Each of these methods has benefits and drawbacks; however, it is commonly producer-dependent on which winter feeding system is used on their operation.

	Months since calving											
	1	2	3	4	5	6	7	8	9	10	11	12
	-----10 lb peak milk production-----											
DM, lb	24.4	24.9	26.0	25.6	25.1	24.8	24.2	24.1	24.0	23.9	24.1	24.6
TDN, %	55.3	56.0	53.7	52.9	52.1	51.5	44.9	45.8	47.1	49.3	52.3	56.2
CP, %	8.4	8.8	8.1	7.7	7.3	7.0	6.0	6.2	6.5	7.0	7.7	8.8
Ca, %	0.24	0.25	0.23	0.21	0.20	0.19	0.15	0.15	0.15	0.26	0.25	0.25
P, %	0.17	0.17	0.16	0.15	0.14	0.14	0.12	0.12	0.12	0.16	0.16	0.16
	-----20 lb peak milk production-----											
DM, lb	26.8	27.8	28.4	27.4	26.5	25.7	24.2	24.1	24.0	23.9	24.1	24.6
TDN, %	58.7	59.9	57.6	56.2	54.7	53.4	44.9	45.8	47.1	49.3	52.3	56.2
CP, %	10.1	10.7	9.9	9.3	8.5	7.9	6.0	6.2	6.5	7.0	7.7	8.8
Ca, %	0.29	0.31	0.29	0.26	0.24	0.22	0.15	0.15	0.15	0.26	0.25	0.25
P, %	0.19	0.21	0.19	0.18	0.17	0.15	0.12	0.12	0.12	0.16	0.16	0.16
	-----30 lb peak milk production-----											
DM, lb	29.2	30.6	30.8	29.4	27.9	26.7	24.2	24.1	24.0	23.9	24.1	24.6
TDN, %	61.6	63.2	60.8	59.0	57.0	55.2	44.9	45.8	47.1	49.3	52.3	56.2
CP, %	11.5	12.3	11.4	10.6	9.6	8.8	6.0	6.2	6.5	7.0	7.7	8.8
Ca, %	0.34	0.36	0.34	0.31	0.27	0.25	0.15	0.15	0.15	0.26	0.25	0.25
P, %	0.22	0.23	0.22	0.20	0.18	0.17	0.12	0.12	0.12	0.16	0.16	0.16

Adapted from Nutrient Requirements of Beef Cattle (National Research Council, 2000)

Figure 1. Nutrient requirements of beef cows at 1200lbs mature weight (National Research Council, 2000).

The latter method of bale grazing has recently been receiving attention by scientists and beef cattle producers alike in the NGP. This is mainly because bale grazing has shown to have a low labor input, as well as reduced winter feeding inputs; these advantages are promising to producers when it comes to winter feeding (Lardner et al., 2008). The adoption of extended grazing techniques, such as bale grazing, is driven by producers wanting to reduce winter feed costs, along with inputs that are associated with winter feeding cattle in dry lots (Kelln et al., 2011; D'Souza et al., 1990). Bale grazing has also been shown to benefit the ranching ecosystem as a whole, as it puts cattle "back on the range" as to say, and out of the dry lot pen for a greater length of time throughout the year (Ross and Kaliel, 2011).

Starting from the ground up, one of the first advantages of bale grazing includes improved soil health conditions when feeding on either crop fields, or tame hay fields and grasslands. This is seen through higher nitrogen levels in the soil due to the additions of direct urine and manure, and the accelerated break down of old, standing forage from the hoof action of the cattle (Jungnitsch, 2005; Jungnitsch et al., 2011; Kelln et al., 2012). With improved soil health, a second advantage of increased forage production, either crop or grassland plants, could also be seen within the bale grazing area. This increase in forage production can lead to higher crop yields or grass stands, creating a higher efficiency rate in terms of sustainability, ecological health and capital (Kelln et al., 2007).

Although all these aforementioned advantages can be seen from bale grazing, ranchers are likely to be more concerned with the nutrition requirements of their beef cattle during the winter season. Adequate nutrition (namely energy and protein) is vital during wintertime feeding to ensure cow maintenance and proper rumen function (Koster et al., 1996). Achieving adequate nutrition comes down to the type and quality of forage being fed while bale grazing. Undi et al. (2017) has showed that nutritional requirements are met while bale grazing, and that there is no

effect on nutrition whether the cattle are bale grazed or fed in a dry lot setting. There are multiple other factors that must be considered while bale grazing that could impact the overall nutrition of beef cattle, including supplementation, water sources, windbreaks or shelter, and overall climatic effects.

Economic considerations are another factor producers must look at when considering bale grazing. Because ranchers are looking for the most cost-effective, least labor intensive, and overall most efficient option when it comes to winter feeding, economics largely must be considered. When implemented properly, bale grazing can be the least labor-intensive winter feeding method because there is no need to use a tractor every day to transfer and feed forage to cattle. Tractor use is also eliminated when it comes to hauling manure and bedding from the pen to the field the following spring, as it is directly deposited to the field (Lardner, 2005a).

In a bale grazing setting, the bales are set out on a field or pasture at the beginning of the winter season, or ideally let lay on the hay field after they are baled, and then cows allowed to graze them freely. This method can cut labor in half, as the producers likely will only need to check their cattle and forage status of the bales being grazed; usually checking can be done once a day, or even every other day. Several ranchers take interest in this reduction of labor because many of them have jobs off of the ranch and do not have the time to start a tractor every day during the winter to feed hay. Pasture visits, along with the duration of feeding can be highly reduced with the implementation of a bale grazing system. The majority of the time a tractor needs to be used is concentrated in the fall of the year when the bale grazing system is set up (Manitoba Agriculture, Food and Rural Initiatives Centre et al., 2008).

Cost goes along with labor when it comes to bale grazing. The opportunity cost of reduced labor, reduced daily fuel expenses for starting and running the tractor every day, and the reduced expense of manure cleanup are all saved when bale grazing. Hauling manure is

completely eliminated when it comes to bale grazing, as the cattle are directly defecating on the field or pasture; making bale grazing more efficient (Lardner, 2005a). This can also be seen as an advantage because the cattle urine, a great source of nitrogen urea, is returned to the grazing area instead of being lost as drainage when in a dry lot setting (Jungnitsch et al., 2011).

Due to the many factors that ranchers consider while winter feeding, bale grazing is often researched on a systems basis, not only looking at beef cattle performance, but also looking at cost-effectiveness, forage production, and soil nutrient composition changes. If bale grazing is done in the correct manner, it has been shown to lead to positive economic and environmental changes including increased cattle performance, lowered costs, improved soil health, increased forage, and decreased labor and nutrient waste. Overall, scientists are interested in researching the economic and ecological benefits of the bale grazing method of winter feeding.

Overview and Purpose of Bale Grazing

Bale grazing can be defined as a process of low-maintenance winter feeding, in which the livestock feed themselves. The bale grazing winter feeding system allows cattle to forage hay directly at the source, which reduces reliance on producer inputs such as labor, energy, and machinery use (Saskatchewan Forage Council, 2011). This can lead to decreased production costs for winter feeding and increase overall profitability of beef cattle operations. In a bale grazing system, large amounts of hay bales are set up at a site in the fall before winter feeding begins, and then the cows are allowed to graze the bales freely when feeding starts. Bale grazing systems can be set up in many different ways, depending on the preference of the producer. A simple bale grazing winter feeding system can be laid out in the following way:

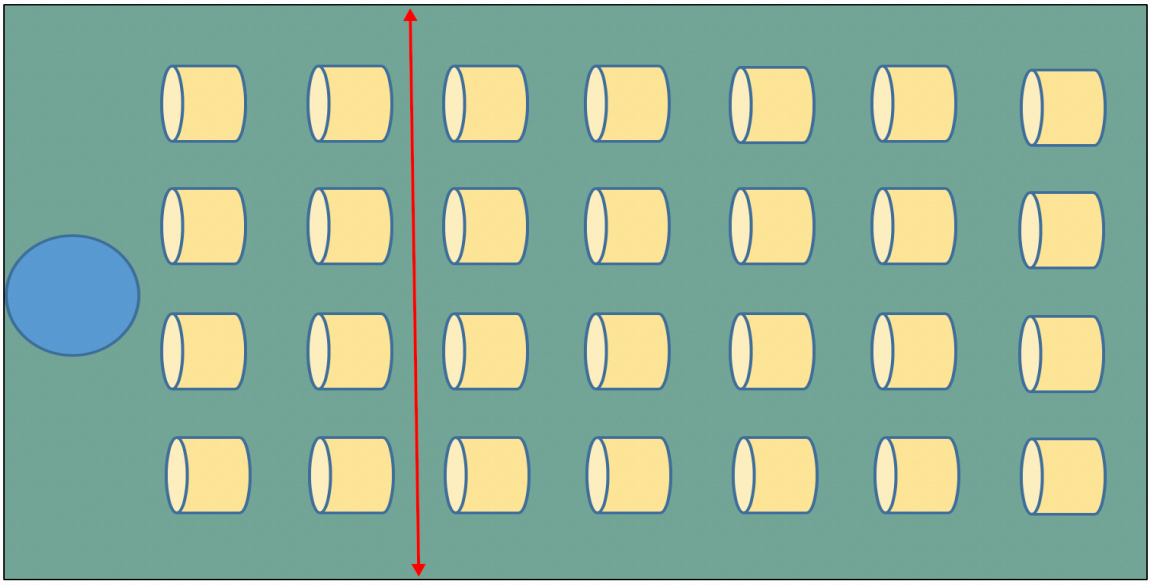

Figure 2. Simple bale grazing setup including a parameter fence, water source, and moveable cross fence to allow strip grazing.

In the system illustrated in Figure 2, cows are allowed to roam freely and graze on bales of their choosing between the water source and moveable cross fence. To set up this system, the hay bales are made with a tractor and baler, then let sit in their exact spot on the hay field for bale grazing. Specific spacing of the bales would depend on the amount of forage that is produced by the field. Often times, producers must re-place bales to achieve a specific spacing pattern; with this, depending on hay quality outside bales may need to be added to meet cattle nutrition needs. The cows are moved into the field to feed on the bales when winter feeding begins. In many bale grazing systems, there is no labor needed to stack and haul the bales off of the field, or to haul the bales back to the cows and feed them.

A viable water source must be available throughout the winter to ensure practicality of a bale grazing system. Many producers may also want to use a cross fence to ensure that the cattle clean up all loose hay before allowed to graze new bales. Cross fencing will help regulate the amount of hay cows are allowed to intake, forcing cattle to maximize efficiency of hay resources and minimize waste (Munson et al., 1999). Manure and urine distribution will also be more

uniform throughout the bale grazing pasture or field when using a cross fence, which will create more even soil nutrient distribution (NRCS, 2016). Where to place the cross fence in the bale grazing area is a decision for the producer based on how often they want to move the fence and allow their cows to graze on new bales.

When winter feeding in a bale grazing system, labor is largely reduced as the rancher will not have to feed cattle every day. Simply, the cattle will need to be checked every couple days to ensure water availability and adequate hay reserves. As earlier noted, the time and cost of hauling hay after made is essentially eliminated because the bales are grazed in the field that the hay is made.

However, in other bale grazing systems the bales may need to be moved and placed on a bale grazing field or pasture. This may be the case if hay fields are not near a water source, or not in an area that is acceptable for winter feeding cattle. In this situation, bales will need to be set in a pasture or field that is selected for the bale grazing area before the winter feeding period begins. Either way, there is the added benefit of not having to haul manure out of the dry lot onto the field, as the cattle will directly deposit it onto the field or pasture. This will ensure that the maximum nutrients that are excreted by the cattle are applied directly onto the pasture or field. The Manitoba Agriculture, Food and Rural Initiatives Centre states that a producer-based bale grazing system should be set up in the following way (Figure 3). The bales should be set at least 9 meters from each other in a checkerboard pattern, to ensure even manure coverage throughout the bale grazing site (Manitoba Agriculture, Food and Rural Initiatives Centre et al., 2008). Producers should set up the bale grazing site at least 100 meters away from any type of surface water to avoid runoff from entering into water sources, as shown in Figure 3. A good source of shelter, such as wind breaks or trees should be available to the cattle throughout the bale grazing period. It is also recommended to use a high voltage energizer with wire electric cross fence, as

snow acts as an insulator and will weaken electrical shock to livestock (Manitoba Agriculture, Food and Rural Initiatives Centre et al., 2008).

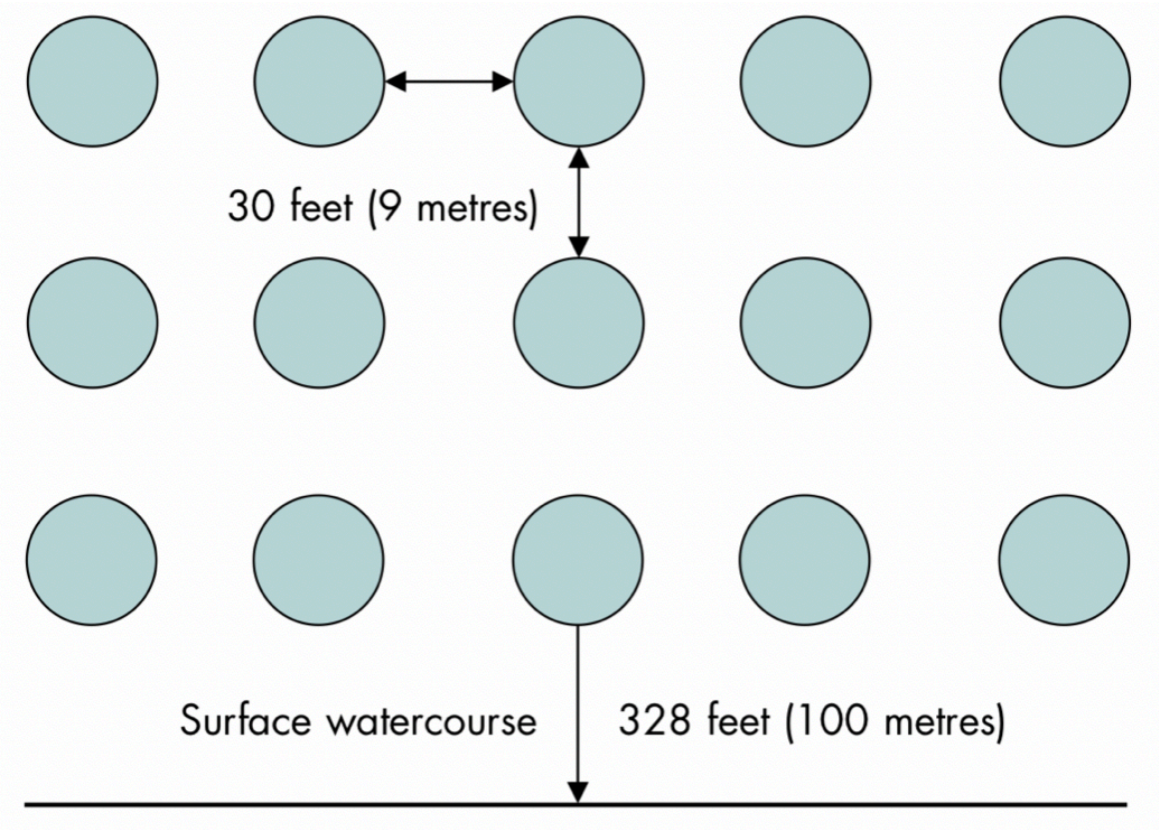

Figure 3. Manitoba Agriculture, Food and Rural Initiatives Centre producer-based bale grazing setup (Manitoba Agriculture, Food and Rural Initiatives Centre et al., 2008).

Another bale grazing system may be set up similar to Undi et al. (2017). In this system designed by Undi et al. (2017), a 10.5 hectare hay field was spilt into four equal paddocks (Figure 4). Bales were placed 9 meters apart throughout all of the paddocks. A cross-wire fence was placed across the paddocks every four bales to control cow intake and hay waste. The pregnant cows were fed poor-quality Conservation Reserve Program hay (<8% CP) and then supplemented with one of the following three supplements: dried distillers grain with solubles (DDGS), alfalfa hay, or a liquid molasses-based supplement (Undi et al., 2017).

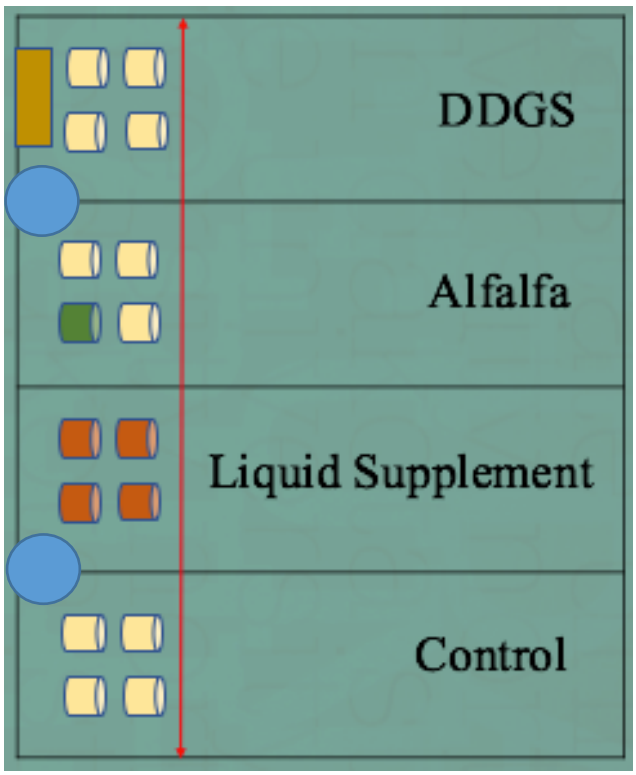

Figure 4. A research-based bale grazing setup with a water source, cross fence, and several different supplementation options (Undi et al., 2017).

This study had two objectives, 1) comparing the winter feeding methods of bale grazing with dry lot feeding, and 2) evaluating supplementation methods during winter bale grazing (Undi et al., 2017). In the first part of the study, the gestating cows in the dry lot were offered the same poor-quality CRP hay that was used in the bale grazing set up. Results indicated there was no difference in cow body weight changes (BW), average daily gain, or body condition score when comparing winter feeding in a dry lot or bale grazing system (BCS, Undi et al., 2017). Undi et al. (2017) found winter feeding in a bale grazing setting has no effect on cattle nutrition. Lardner (2005b) reported similar findings in a study in southern Saskatchewan CD, where they reported no effect on cow BW and BCS when comparing field feeding or dry lot winter feeding.

In the second part of the study, Undi et al. (2017) found that supplementation methods did not affect BW or BCS. However, when cows were supplemented with DDGS while being

fed poor-quality CRP hay in a bale grazing system, ADG and BCS were greater than the other supplement treatments (Undi et al., 2017). Table 1 shows that the nutritional composition of the DDGS supplement was higher for both CP and TDN, indicating that when early to mid-gestating cows are bale grazing low quality hay and supplemented with DDGS their nutritional needs can be met. Undi et al. (2017) indicated that cows are capable of maintaining, or even gaining weight in a bale grazing system when nutrition is adequate. When bale grazing, hay quality must be considered and if it is too low to meet cow nutritional needs, a supplement should be provided.

Table 1. Composition of grass hay (control), grass hay supplemented with alfalfa hay, liquid protein supplement-treated grass hay, or grass hay supplemented with distillers grains with solubles (DDGS) (Undi et al., 2017).

	Grass hay control	**Grass hay with alfalfa hay supplement**	**Liquid protein supplement-treated grass hay**	**Grass hay with DDGS supplement**
Dry matter (DM), %	94.3	94.1	86.4	93.7
Crude protein	7.5	9.9	8.8	11.1
Total digestible nutrients	51.7	54.1	51.0	55.2
Neutral detergent fiber	66.3	63.5	65.9	60.9
Acid detergent fiber	47.8	44.7	48.7	42.6
Calcium	0.56	0.91	0.51	0.48
Phosphorus	0.10	0.11	0.16	0.25
Potassium	0.77	1.03	0.93	0.84
Magnesium	0.18	0.23	0.15	0.21

In 2014, Lardner et al. (2014) evaluated heifer development while winter feeding in a bale grazing system. The design of this bale grazing system set up shown in Figure 5. Lardner et al. (2014) had four hectare pastures divided into four paddocks (Figure 5). Forty-two smooth bromegrass/alfalfa mixed bales were set in each paddock approximately 17 meters across and 12 meters in length from each other. An electric fence crosswire was used to control heifer grazing for 3-day increments. A central water tank, along with windbreaks were used in the setup for this bale grazing study (Lardner et al., 2014).

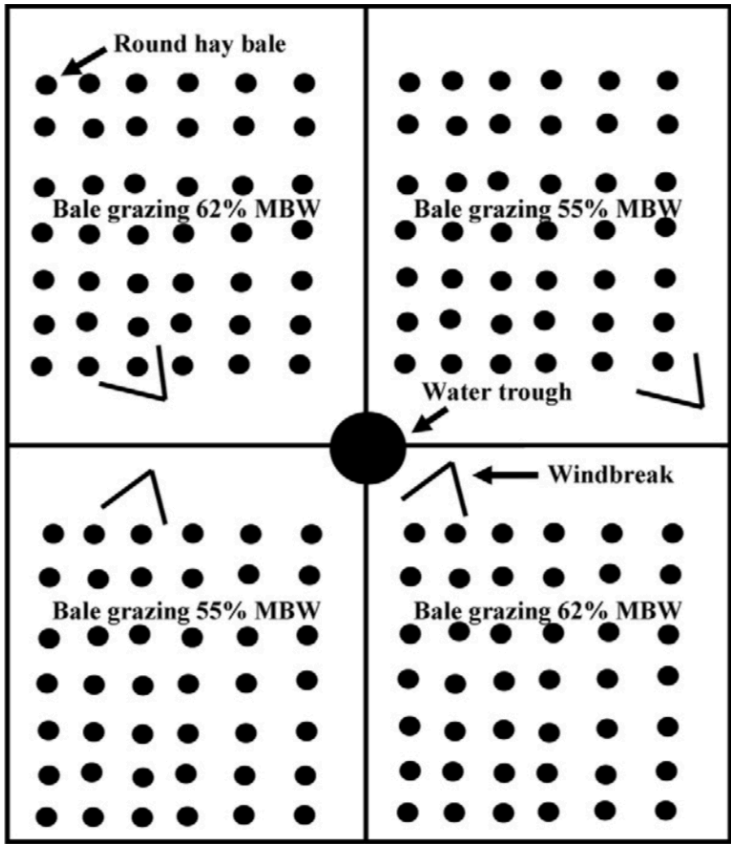

Figure 5. Lardner research-based bale grazing setup: Plan of the bale grazing site showing four paddocks (100x100m each) and the location of bales, water troughs, and windbreaks (Lardner et al., 2014).

Developing beef heifers were fed in the bale grazing setting, or dry lot setting at two different supplementation levels to reach either 55% or 62% mature body weight (MBW); then exposed to bulls to be bred (Lardner et al., 2014). This study showed the bale grazing system and dry lot setting had similar pregnancy rates, and did not have a negative effect on heifer development. There was also no difference in the first-calf heifers BW at weaning. Lardner et al. (2014) concluded heifers raised in a bale grazing setting had a 6% economic advantage over the dry lot setting when looking at feed, bedding, labor, equipment, depreciation, repair, and manure costs.

Nonetheless, Lardner et al. (2014) cautioned that heifer intake was limited on the bale grazing system at some points of the study, likely due to extremely cold temperatures and snowfall. Because of this, producers must take adequate precautions when bale grazing in extreme climates such as ensuring proper shelter and possible supplementation when needed. Many other considerations must be looked at to ensure beef cattle are being cared for properly when bale grazing during the winter season. Moreover, if considerable precautions are taken several studies have shown that winter feeding in a bale grazing system show no difference in cattle performance when compared to a dry lot feeding setting.

Considerations of Bale Grazing

When bale grazing, ranchers must consider the risks associated with managing cattle during the winter season in an uncontrolled setting, such as an open pasture or field, especially when compared with the average winter feeding setup such as a pen near the home place. Ranchers must supply a source of shelter, either natural or portable windbreaks, lean-to shelters, tree groves, or other sources of protection from wind and snow. As noted in a previous study, cattle will likely reduce or stop feeding if exposed to extreme winter conditions (Lardner et al., 2014).

The adverse climate in the Northern region of the United States and Canada may cause producers to terminate their bale grazing efforts early. When there are large amounts of snowfall, the bales in the bale grazing area may become so snow covered that cows are no longer able to forage. In this situation, ranchers are faced with a tough decision to pushing snow away from the bales with a tractor so cows can feed, or bring cattle home and feed them in a different setting. An important factor to consider when planning on winter feeding in a bale grazing system is to have a backup plan in place in case the early termination of the system is required. Again, bale

grazing site selection is crucial to ensure adequate protection. Especially where there is potential for blowing snow to cover the bales to assure that winter feeding in a bale grazing system will be successful.

The location of the bale grazing pasture or field is a critical consideration. When choosing a bale grazing site is if cattle are no longer able to feed in the bale grazing area, the livestock producer must be able to get them home or to another location safely. Another consideration is the land status of the site; native rangeland should never be winter fed or bale grazed on as it has negative impacts on native plant communities. Moreover, if invasive grass plant species are used as feed in hay bales while bale grazing, invasive seed will be detrimental to the native rangeland and take over the existing native plant species (Kelly, 2018). Instead, producers should use a tame grassland area, or hay or cropland field that needs soil fertility improvement for the bale grazing site (Chen et al., 2017).

The bale grazing site must also have a reliable source of water throughout the winter to ensure that the cattle will not get dehydrated. In the most parts of the Northern Great Plains when weather gets cold, producers will likely have to check water daily to ensure it does not freeze. If cows are trained, they may be able to suffice on eating snow as a water source. A Canadian study by Degen and Young (1991) showed that beef cows can rely purely on snow as a water source during the winter and have no adverse effects on calf production. Nonetheless, several of the NGP states do not have snow on the ground throughout the entire winter, so it should not be relied on as the main source of water for cattle when bale grazing.

If a livestock producer chooses to cross fence their bale grazing setup, more complications could also arise. When using a one-wire electric cross fence, various producers have noted that deer, pronghorn, or even elk will displace the cross fence and drag it down the field, thus causing it to be ineffective to keep cattle in one area of the bale grazing field. Another

problem reported in a study with an electric one-wire cross fence was that the cows would run through the cross fence during winter storms and move themselves to a fresh set of bales (Undi et al., 2017). Karhu et al. (2010) concluded to effectively keep cattle enclosed and keep deer, pronghorn, and elk restricted with an electric three-wire cross fence should be used. However, an electric three-wire cross fence can be cumbersome to move throughout the winter with the cold weather. For this reason, may ranchers choose not to cross fence their bale grazing pasture and simply allow the cattle to graze freely throughout the entire setup.

After a site is selected for the bale grazing area, a producer can begin to plan the setup process. Setup usually takes place in late fall after (or while) hay has been baled. To be the most efficient and economical, it would be beneficial for producers to use a bale grazing system that encompasses the simplest method of letting the bales set in their exact spot they were baled on. Essentially, beyond swathing and baling the hay, this system uses no tractor or labor to winter feed cattle. When using this system, it is important to note that there is no specific setup, as the bales are simply let set where they are made. This could make it difficult for producers to cross fence the field, as the bales will likely not be spaced evenly. Although the setup for this system is very easy and convenient, in some situations this may be unrealistic as they may not put up their own hay, or they may not have a centrally located hay field (with water available) that could be used for the bale grazing system.

Another concern is the quality of the hay that is produced by the field, and the hay residue that may be left on the pasture or field. In many situations, producers will not consider hay residue a negative result of bale grazing, as it can be used as bedding for livestock and in turn adds important nutrients back into the soil. Selecting an area that is lacking vital soil nutrients for the bales grazing site will improve overall operation efficiency and nutrient cycling.

A second setup option for producers would be to re-place the bales in another location after they have been baled. This is often done by the producer, as it is more convenient to bring the hay closer to home and bale graze in an area that is easily accessible during the winter and has an established water source. Sedivec et al. (2018) recommended that if possible, bales should be placed 15 to 17 meters feet apart in a checkerboard pattern. At this distance, bale waste was reduced because hay selection is lessened, and manure and urine are more scattered than if the bales were set closer together. Even distribution of bale waste, manure, and urine led to better soil health conditions, and thus higher forage production (Sedivec et al., 2018).

After the bales are placed in the bale grazing area, the twine or net wrap should be removed from the bales. Although it was noted in one study that bale waste could be lessened if the net wrap was taken off closer to grazing; however, it is impractical to try and remove net wrap from hundreds of snow-covered bales (Undi et al., 2017). It is important to remove the twine or net wrap from the bales, so it does not build up on the bale grazing site and cattle have easy access to the hay. Bales should be set on their sides to reduce hay waste as well. After the bales are setup, a producer will ensure that a water source is available and working at the bale grazing site. Portable windbreaks and shelters should also be put in place in the fall before snowfall. The cross fence could also be setup at this time if the producer chooses to do so.

One issue that may arise after bale grazing is a manure or hay residue build up in the bale grazing site. If the cows are not forced to clean up the hay during the bale grazing in the winter, it will likely accumulate in the spot of the bale and not allow forage growth under it. Because hay waste is largely a concern among producers when bale grazing, it would be recommended to use a cross fence to force the cattle to clean up all of the excess hay. Accumulation of wasted hay is accelerated if poor quality forage is used, as cattle refuse to eat it unless forced. To minimize this, producers should make sure to use the highest quality hay possible so cows will clean it up

from the bale grazing site. Manure accumulation can also be lessened if the hay bales are spaced at least 10 meters apart from each other or, even further such as 17 meters apart in the previously mentioned study (Sedivec et al., 2018). If bales are spaced too close together, manure will pile up and not quickly breakdown; thus, not allowing forage to grow through the manure buildup.

In areas of the bale grazing site where excess manure, urine, and hay residue become concentrated, surplus nutrients can easily accumulate and cause hot spots in the pasture or field (Manitoba Agriculture, Food and Rural Initiatives Centre et al., 2008). To combat excess nutrient problems and create a more even nutrient plane throughout the area, livestock producers could rake or spread out the hay residue and manure with a drag which will allow it to break down more uniformly throughout the field or pasture. Another option would be to heavily graze the area the following summer to allow livestock to trample and break down the hay residue and manure with their hoof action (NRCS, 2016). Kelln (2012) also recommends the use of an annual cropping system to control excess soil and manure nutrients. Additionally, Omokanye (2013) recommends monitoring residual soil nutrients by soil testing the years following a bale grazing system to ensure soil nutrients are within the proper levels. However with the proper set up, including the recommended bale spacing and management, excess nutrient problems should be minimized after bale grazing.

Another issue that could emerge in the spring following bale grazing is an outbreak of noxious weeds in the pasture or field in the bale grazing site. Noxious weed outbreaks, such as Canada thistle, could be a problem if weed-free hay is not used in the bale grazing area. Producers should be on the lookout for any early onset of noxious weeds in the spring and be proactive about spraying weeds with herbicide to ensure they do not infest the bale grazing pasture or field. If left uncontrolled, noxious weed outbreaks the could decrease crop or forage productivity and yield in the bale grazing area (DiTomaso, 2000).

Summary

When producers are considering implementing a bale grazing system for winter feeding, there are multiple factors to examine. First and foremost, producers should always have a backup plan incase their bale grazing system fails. After that, they must make sure the site chosen is appropriate and has accessible water, shelter, and protection from the winter elements. Overall, producers must consider all of the positive and negative impacts that using a bale grazing system for winter feeding will have on their livestock operation, to ensure it is the appropriate choice for their farm or ranch.

With careful and proactive management, bale grazing can be the best option on many ranching operations throughout the NGP, as it is often the most efficient and economical winter feeding system. Several ecosystem-wide benefits can be achieved when using bale grazing as a winter feeding method, including but not limited to: improved soil health conditions, increased forage production, enhanced livestock nutrition, and considerable economic gain. Together, all of these will lead producers to create a healthier and more profitable ranching operation (Ross and Kaliel, 2011).

BALE GRAZING IMPACTS

Bale grazing research has tested the effects it has on soil health, forage production, livestock nutrition, and economic considerations. Multiple studies have shown bale grazing can have a positive impact on the entire ranch ecosystem (Jungnitsch et al., 2011; Ross and Kaliel, 2011; Omokanye, 2013; Kulathunga et al., 2016; Chen et al., 2017). The advantages can be seen in many ways, including: decreased nutrient waste and more efficient nutrient cycling, improved soil health conditions, increased forage production and quality, improved livestock nutrition, lowered production costs, and a decrease in machinery use and labor.

Soil Health and Forage Production

Several research trials have shown an increase in specific soil nutrients, including nitrogen and phosphorus, along with organic matter while field or bale grazing. Organic matter is among the most important component in determining soil fertility, and in turn forage growth and production (Tabatabai 1996). Decomposed animal and plant residue, including cattle waste (urine and manure) comprise most soil organic matter. When bale grazing, the direct additions of manure and urine from cattle encourage greater nutrient cycling and higher organic matter in the bale grazing field or pasture, and less nutrient waste as is lost in a traditional dry lot setting. With greater nutrient cycling, namely N, P, and K in the bale grazing area, an increase in forage production is an expected consequence (Wood, 1990). Forages are also likely to have a higher nutrient content, as a result of the heightened nitrogen content and organic matter in the soil. Conclusively, the following studies show how using a bale grazing system for winter feeding can improve the environmental health of a ranching operation.

Lardner (2006) showed that hay residue is a valuable soil nutrient source when bale grazing. When cows are naturally allowed to directly deposit manure and waste onto a field or

pasture, rather than being mechanically done by the rancher via hauling manure, overall nutrient cycling is more efficient (Lardner, 2006). This directly correlates with improved pasture or forage growth in the following season. Often, producers view hay residue as a problem when bale grazing; however, this study proves that hay residue should be viewed as a nutrient source or fertilizer for the bale grazing area. Lardner's (2006) study also showed that winter feeding costs can be reduced by feeding in the field instead of dry lot, without compromising cattle performance.

Kelln et al. (2012) showed soils with 53% higher nitrate nitrogen when bale grazing compared to a straw-chaff grazing site. The same study also showed that bale grazing areas had 34% higher phosphorus than on swath grazing or straw-chaff grazing sites. This increase in soil nutrients went hand in hand with crop biomass, showing a 15% increase (Kelln et al., 2012). These results could have likely been seen because of the higher nutrient content of the bale grazing hay when compared to the swath grazing forage or straw-chaff grazing forage, but nonetheless confirm that bale grazing will lead to healthier, more nutrient dense soils.

Jungnitsch et al. (2011) reported soil nutrients, namely inorganic N, were over three times higher on pastures cattle were winter fed on when compared to a dry lot. This correlated to a 3-4 times increase in forage dry matter on the winter fed site compared to a control, and over a one time increase compared when to sites where manure was spread on from the dry lot (Jungnitsch et al., 2011). They showed nutrient cycling was greater on a site where cattle were winter fed compare to dry lot and fields spread with manure. Additionally, the nutrients from the cow urine are absorbed in the soils of the bale grazing site, whereas they are often lost in the dry lot setting. Jungnitsch et al. (2011) concluded livestock producers will save money by not having to haul manure and waste from the dry lot to the field and increase soil nutrients and forage production when using a bale grazing system.

Chen et al. (2017) showed that soil nutrients, including phosphorus and nitrate, were greater after bale grazing, improving soil fertility and organic matter. They also reported a greater amount of runoff of these nutrients when bale grazing, likely due to more nutrients being readily available to runoff into nearby watersheds (Chen et al., 2017). Nutrient runoff into water sources is considered waste and harmful in large amounts. However, with proper bale grazing site selection, producers should be able to control nutrient runoff and create a more efficient nutrient cycle in their bale grazing pasture or field.

A producer-orientated bale grazing trial by Sedivec et al. (2018) showed that soil nitrates, phosphorus, and potassium all increased in the bale grazing treatment when compared to a non-bale grazed control. They also reported an increase in grass production and showed an increase in crude protein content and phosphorus levels in the grass. Grass production was the greatest at 15 feet from the bale center six months following the bale grazing, and had increased at zero, five, and ten feet from the bale center within 18 months; this was likely due to the breakdown of excess hay residue surrounding the bale's original location. Sedivec et al. (2018) concluded that additions of hay waste, urine, and manure lead to an increase in soil nutrients, thus boosting forage production and quality on the bale grazing sites (Sedivec et al., 2018).

In a Canadian study by Omokanye (2013) soil moisture content was shown to be higher in sites that were bale grazed than in non-bale grazed sites. Soil organic matter was significantly higher after three years of bale grazing on the site, when compared to the beginning, first, and second years of the study; these results indicate that bale grazing will benefit soil nutrient accumulations years following bale grazing. This study also showed the main soil nutrients; N, P, K, and S had an interaction between bale grazing and soil depth, resulting in a forage yield almost five times the amount on the control site (Omokanye, 2013). The resulting forages also had a higher crude protein content in the vegetation on the bale grazed system compared to the

non-bale grazed sites (Omokanye, 2013). The interaction between soil nutrients and forage production and quality is clearly outlined in the aforementioned study, concluding that bale grazing had a positive effect on soil health, and therefore forage production.

In a study by Kulathunga et al. (2016), they showed soil nitrate nitrogen and organic carbon were greater when grazing stockpiled perennial forage in field paddocks than when feeding hay bales in a dry lot pen. They also found no difference in cow BCS when comparing the two feeding systems, and system costs were almost 14% less when feeding in the field paddocks (Kulathunga et al., 2016). Kulathunga et al. (2016) demonstrated how winter feeding in a field grazing setting can lead to improved ecosystem and economic efficiency of an operation without affecting cattle performance.

Livestock Nutrition

Bale grazing has been shown to be an effective winter feeding strategy for cattle. Many studies have shown when bale grazing is compared with dry lot winter feeding system, there was no effect on cow weight gain, body condition score, or reproductive status. In most scenarios, as long as pregnant beef cows are supplied with adequate nutrition, housing status does not affect livestock performance (Undi et al., 2017). When bale grazing, if the cattle do not receive adequate nutrition through the hay bales alone, producers may need to feed a supplement to maintain animal performance. Overall, bale grazing seems to be a promising alternative, causing no detrimental effects on livestock performance when used as a winter feeding alternative on ranching operations.

A two-year study conducted in central North Dakota showed no difference in pregnant beef cow performance when wintering beef cattle in a bale grazing setting versus dry lot feeding (Undi et al., 2017). Although there was a difference in body weight (ADG) and body condition

score (BSC) from year 1 to year 2, this was likely attributed to the unpredictable climate in the northern region. In 2016 there were multiple extreme blizzards with record snowfall and very cold temperatures, while 2017 was a milder winter. However, there was no difference found when comparing ADG and BCS in the dry lot setting compared the bale grazing system in 2016, and then the same results were repeated in 2017 (Figures 6 and 7; Undi et al., 2017).

Undi et al. (2017) showed bale grazing may be a viable alternative to dry lot for winter feeding pregnant beef cattle. There was an indication that winter feeding using a bale grazing method will mimic winter feeding in a dry lot setting when looking at cattle performance across two extremely different winter seasons. Furthermore, extreme environmental conditions such as blizzards will not necessarily hinder bale grazing when proper precautions are taken to ensure animals receive adequate nutrition and protection from the winter elements (Undi et al., 2017).

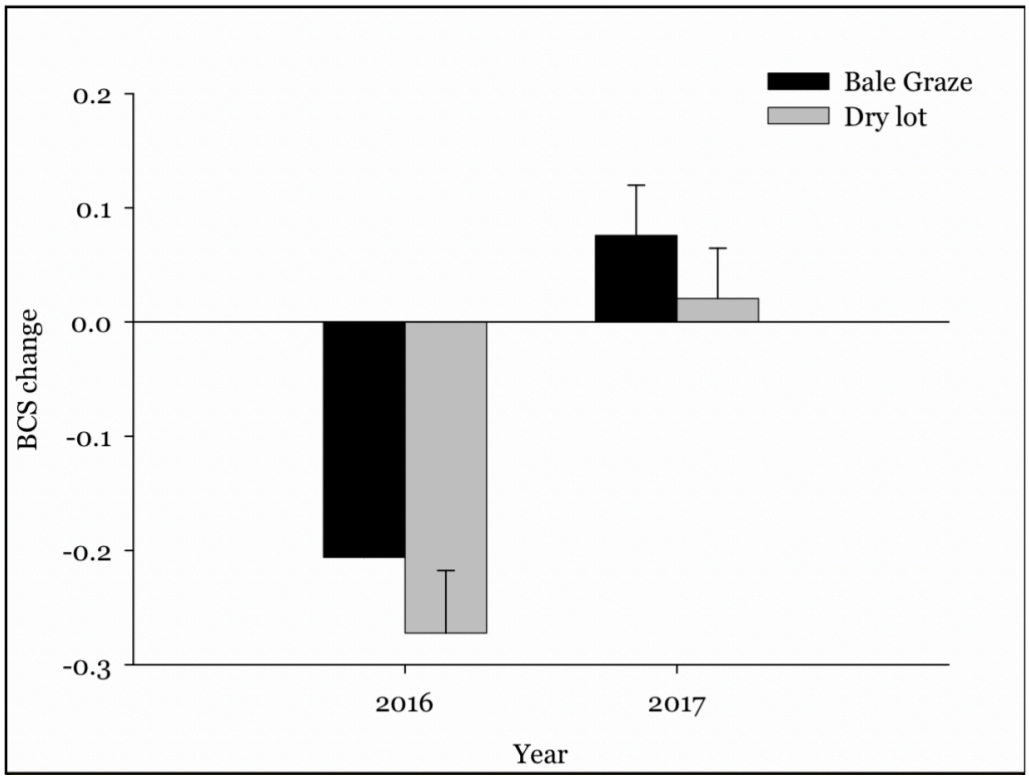

Figure 6. Cow body condition score (BCS) changes on the bale grazing treatment compared to dry lot feeding over two winters (Undi et al., 2017).

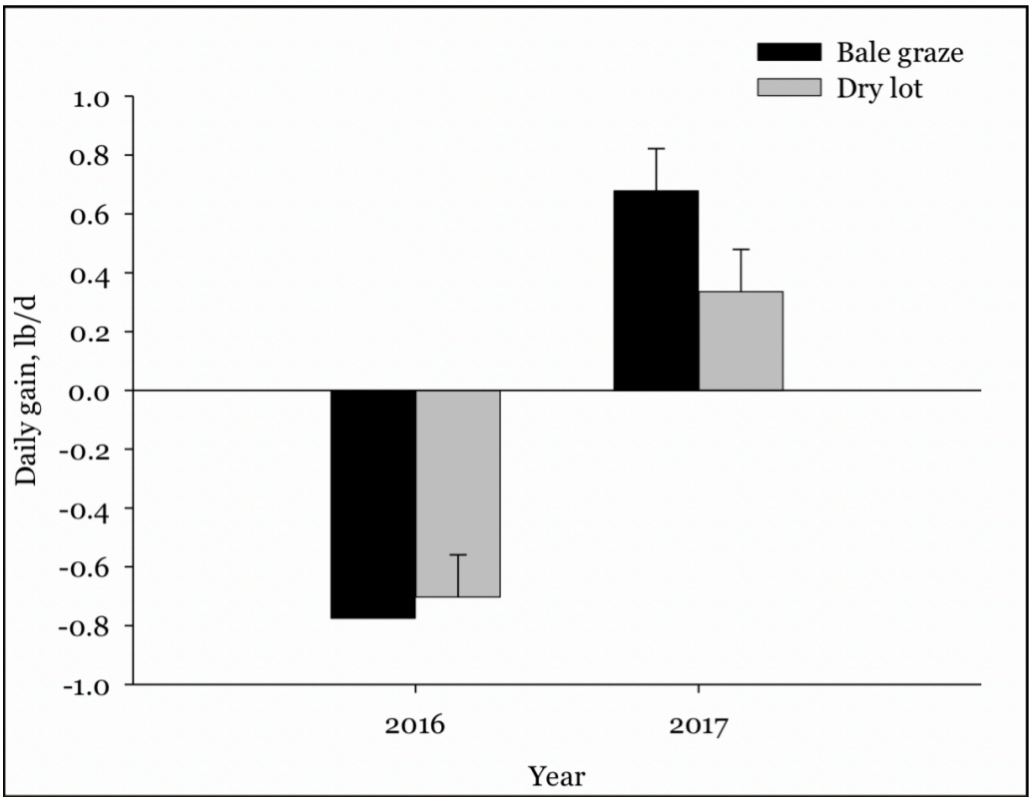

Figure 7. Cow average daily gain (ADG) on the bale grazing treatment compared to dry lot feeding over two winters (Undi et al., 2017).

Similar to Undi et al. (2017), Lardner (2005b) conducted a two-year study that showed winter feeding in a bale grazing setting had no effect on cow body weight or body condition score when compared to feeding in a dry lot or using a bale processor (Undi et al., 2017; Lardner, 2005b). Both years, cows on the bale grazing had a slight increase in BCS, unlike the dry lot or bale processor fed cows (Lardner, 2005b). In the first year, cows in the bale grazing setting had the highest ADG; however, in the second year it was the lowest. Lardner (2005b) also noted that bale grazing was an average of $0.47/day cheaper per cow when compared to winter feeding in a dry lot.

Kelln et al. (2011) compared bale grazing to swath grazing, straw-chaff grazing and winter feeding in a dry lot setting; they showed no effect on cow reproductive performance. This study also concluded cows need a short period of time (21 days) to adjust to a field grazing

setting for winter feeding as they did not gain weight in the first three weeks. After the first three weeks, cows in the bale grazing study gained weight linearly; however, cows in the dry lot gained more body weight. Kelln et al. (2011) also showed that bale grazing costs were eight percent less than winter feeding in the dry lot setting.

Volesky et al. (2002) found calf gains were similar when calves were winter fed using a bale grazing system compared to a windrow grazing method. However, in the first year of the study calves gained more while grazing windrows than while bale grazing. This was likely attributed to high-quality regrowth present in the windrow grazing site (Volesky et al., 2002). Average feed costs were $0.14/day per calf higher for the bale grazing treatment compared to the windrow grazing due to the cost of baling and transporting the hay (Volesky et al., 2002). Nonetheless, winter feeding with a windrow grazing system is often not possible in parts of the NGP, as windrows are easily covered by snow when compared with the bales used in a bale grazing system.

Economic Considerations

Besides cattle nutrition, livestock producers are looking for a winter feeding system that is labor and cost efficient. Bale grazing reduced the labor needed in a winter feeding program; these include moving and stacking hay, starting the tractor every day to haul bales to the cows, feeding bales, pushing up manure, and hauling manure out of the dry lot and spreading it onto fields. Many ranchers hire custom help to do these chores, so the economic savings are easily recognized. Winter feeding is the number one expense for nearly all operations in the Northern Great Plains, and by switching to a bale grazing system these costs can be greatly reduced as shown by many studies (D'Souza et al., 1990; Willms et al., 1993; McCartney et al., 2004; Jungnitsch et al., 2011; Kelln et al., 2011; Baron et al., 2014).

The Saskatchewan Forage Council (2011) found bale grazing is, on average $0.40/day per cow cheaper compared with traditional feeding of hay and straw. This savings is likely incurred from reduced tractor and equipment use, and the elimination of manure removal. However in the same study, bale grazing costs were on average $0.32/day per cow more expensive when compared with aftermath grazing, swatch grazing, and stockpiled grazing; the higher expense is mainly due to the cost to bale, stack, and place bales for the bale grazing site (Saskatchewan Forage Council, 2011). Although bale grazing may not be the cheapest winter feeding system in this study, for many producers it is the most realistic option because with most of the other winter feeding systems that were mentioned, snow will likely cover the forage, making it nearly impossible for cattle to graze on in the NGP. Overall, this study indicated that ranch operating costs can be reduced by switching to a bale grazing system (Saskatchewan Forage Council, 2011).

Teno (2016) conducted a cost-benefit analysis of extending the grazing season in Atlantic, Canada. This study found the cheapest way to feed cattle in the winter was the use of stockpiled forage and bale grazing, and a combination of these two systems was the most economically efficient due to cattle grazing stockpiled forages until snow cover, and then bale grazing to save on expenses. According to Teno (2016), Canadian ranchers can reduce costs between $3,646 to $14,704 per year by switching to a combination winter feeding system of stockpiled forage and bale grazing from a conventional feeding system, depending on the size of their operation. These reduced expenses are realized in feed, yardage, bedding, labor, and other operating costs. Teno (2016) also noted that cattle are able to sustain good performance in BCS and body weight while bale grazing.

In a study by Jungnitsch (2005), bale grazing and the use of a bale processor were both very similar in cost, considering both are field winter feeding methods. However, bale grazing

was $0.33-$0.40/day per cow less than feeding in a dry lot setting, mainly due to savings in machinery use and manure removal. Soil nutrients (nitrogen and potassium) were 1.5 to three times higher in the field feeding sites after winter feeding and forage production increased on average 2.5 times in the field winter feeding settings (Jungnitsch, 2005). This study also concluded that cattle gain and condition were similar, whether feeding in a dry lot or field setting (Jungnitsch, 2005).

Ross and Kaliel (2011) examined beneficial management practices for winter feeding, including bale grazing, swath grazing, bale processing, stockpiled feeding, and dry lot feeding. Their study concluded that total production costs for a swath and bale grazing winter feeding system would the most economically efficient method at $601.71, compared to $624.91 for feeding with a bale processor and $741.92 for dry lot feeding. They also indicated that feeding in a dry lot setting had a large negative impact on surface and groundwater due to surface waste runoff; whereas this affect is reduced when using a field based grazing system such as bale or swath grazing. Ross and Kaliel (2011) recommended that producers switch to a bale or swath grazing winter feeding system as it was more cost effective and environmentally safe.

The previously mentioned study by Kelln et al. (2011) compared four winter feeding systems over the course of three years, bale grazing, swath grazing, straw-chaff grazing, and dry lot. This study showed that bale grazing total costs over the three years were on average eight percent less when compared to winter feeding in a dry lot. Total costs included feed, supplement, labor, equipment, and manure cleaning per cow per day (Table 2; Kelln et al., 2011). In the bale grazing system, feed was $0.03 cheaper than the dry lot, and equipment use was $0.06 cheaper, making the bale grazing system $0.09/day per cow cheaper than feeding in a dry lot. Bale grazing also showed to be $0.29/day per cow cheaper than straw-chaff grazing system, but was

$0.22/day per cow more expensive than swath grazing due to the cheaper feed cost (Table 2; Kelln et al., 2011).

Table 2. Three-year economic analysis comparing winter feeding systems, based on per cow per day (Kelln et al., 2011).

Item	Bale grazing	Swath grazing	Straw-chaff grazing	Drylot
Feed cost	0.83	0.31	0.16	0.86
Supplement	—	—	0.72	—
Labor	0.07	0.20	0.10	0.04
Equipment	0.08	0.25	0.29	0.14
Manure cleaning	—	—	—	0.03
Total cost	0.98	0.76	1.27	1.07

The current research shows that bale grazing will not have a negative effect on cattle performance when compared to feeding in a dry lot winter feeding system. However, when comparing the economic efficiency of bale grazing to the traditional dry lot winter feeding, bale grazing reduced production costs and decreased the reliance on machinery use and labor. This brings hope to many producers, as reduced winter feeding expenses can be achieved without sacrificing cattle performance.

CONCLUSION

Multiple studies have shown that bale grazing can be a promising alternative to conventional winter feeding methods in the Northern Great Plains. Livestock producers wanting to improve soil health conditions and forage production and quality, while reducing operating expenses, machinery use, and labor should consider switching to a bale grazing system. Moreover, several studies have shown winter feeding in a bale grazing setting will not have a negative effect on beef cattle performance in terms of body condition score, body weight, and reproductive performance when compared to feeding cattle in a dry lot setting.

Winter feeding beef cattle in a bale grazing setting has been shown to be more environmentally safe in terms of waste runoff, nutrient loss, soil health, and forage production and quality. Bale grazing can help producers create a more sustainable ranching operation. When performed correctly, bale grazing is one of the most economically effective and environmentally positive winter feeding methods.

FUTURE RESEARCH

After reviewing the current research on bale grazing, some gaps in the literature appeared. Several studies reviewed the affect bale grazing had on soil health and nutrients, but failed to consider the impacts it may have on soil compaction and bulk density. Site selection for bale grazing is crucial; the Manitoba Agriculture, Food and Rural Initiatives Centre et al. (2008) recommended that the bale grazing site should be at least 100 meters away from water sources to avoid runoff. However, limited literature was found that referenced the environmental impact that bale grazing has, namely on the quality of nearby water sources. Further research on bale grazing runoff and watershed analysis must be conducted to draw conclusions. Overall, future bale grazing research should be conducted on a systems basis, looking at the impact it has on the entire ranching ecosystem while focusing on soil health, forage production and quality, livestock performance, and operation economics.

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