THE EFFECT OF FEEDING TECHNOLOGIES ON HAY UTILIZATION BY BEEF CATTLE

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Abstract: Experiment 1 was conducted with Angus and Angus X Hereford cows (n = 72; 532 ± 59 kg) that were allotted by BW to one of two treatments. Treatment 1 (CONT; control) included ad libitum access to a steel ring feeder and 0.45 kg/d of a 38% CP cottonseed meal based supplement. Treatment 2 (LIMIT; limited) included 7 h access to a modified cone feeder and 0.45 kg/d of a 38% CP cottonseed meal based supplement with 200 mg/hd inclusion of monensin (MON). Cows were allotted to one of four previously grazed 1.0 ha paddocks with a 12.2 x 7.6 m^2 concrete pad. Experiment 2 was conducted with the same pads and similar treatments as experiment 1. Lactating cows (n =36; 528 ± 63) were allotted to one of two treatments. Treatment 1) (CONT; control included ad libitum access to a ring feeder with prairie hay and 1.13 kg/d of a protein supplement. Treatment 2 included 6 h access to a modified cone feeder with ammoniated prairie hay and 0.79 kg/d of a wheat middlings and cottonseed meal based pellet.

In experiment 1 There was no difference (*P* = 0.41) between d 0 and off test BW change for cows receiving between treatments. Hay waste was reduced (*P* = 0.01) by the LIMIT treatment. There was a reduction (*P* = 0.01) in percent of bale weight wasted with the LIMIT treatment wasting 11.9%, compared to 24.9% in the CONT treatment. Improved hay efficiency resulted in a decrease in cost of hay and supplement/cow of $.32/d. In experiment 2 there was no difference (*P* = 0.14) in cow BW change between d 0 and off test. However, calves from cows receiving the LIMIT treatment gained less weight (*P* = 0.01) than those receiving the CONT treatment. Total hay waste was significantly (*P* = 0.01) reduced by the LIMIT treatment. Total waste was 134 and 48 kg for CONT and LIMIT treatments, respectively. CONT treatment wasted 21.9% of bale weight, compared to 7.3% for the LIMIT treatment. There was no economic benefit for the LIMIT treatment for the feeding period observed.

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CHAPTER I

INTRODUCTION

The arrival of high priced corn has had a substantial impact on cow-calf herds in the Great Plains. Protein supplement, and in more recent years, hay have traditionally been fed to gestating and lactating beef cattle to meet protein and energy requirements. Feed for cattle is the largest cost in maintaining a beef cow herd, resulting in over 60% of total herd costs (Miller et al., 2001). The influx of high priced corn and the intermittent drought has caused these traditionally cheap feed sources to become more expensive, having a large impact on profitability. The round bale today is the most common form of baled hay found in a beef operation (Belyea et al., 1985) The increase in popularity of the round bale has made hay feeding less labor intensive and extremely popular, causing producers to become dependent on feeding harvested forage to maintain cow performance. Increasing hay prices have made round bales less economical to feed. Round bale feeding has been shown to be extremely inefficient, with waste per bale exceeding 20% (Sexten et al., 2011). There are many technologies available to improve efficiency of hay utilization by beef cows. Each technology has shown to improve the efficiency or economics of feeding hay to beef cattle. There is very little research, however, regarding the effectiveness of combining several hay feeding technologies. The objective of this thesis is to determine the effects of round bale feeding technologies on hay utilization by beef cattle.

LITERATURE CITED

Belyea, R. L., F. A. Martz, and S. Bell. 1985. Storage and feeding losses of large round bales. J. Dairy Sci. 68:3371-3375.

Miller, A. J., D. B. Faulkner, R. K. Knipe, D. R. Strohbehn, D.F. Parrett, and L.L. Berger. 2001. Critical control points for profitability in the cow-calf enterprise. Prof. Anim. Sci. 17:95-302.

Sexten, A, J., The effects of hay processing and feeder design on hay utilization. . Marter's Thesis. Oklahoma State Univ., Stillwater.

CHAPTER II

LITERATURE REVIEW

FACTORS TO IMPROVE EFFICIENCY OF HAY UTILIZATION BY BEEF COWS

In the southern Great Plains bailing hay during the active growing season to be fed to cattle during the winter is a common practice. Harvested forage or "hay" is provided to either supplement the current nutritional plane of the cow or to provide roughage when none is available. Vestal (2007) reported that 45% of producers in Oklahoma feed hay between 91 and 120 days (d) every year. Providing feed to beef cattle can account for over 60% of the total costs per year for a cow-calf operation (Miller et al., 2001). Costs associated with feeding hay have a major impact on the profitability of many cow-calf operations. Increasing hay feeding efficiency could have a major economic impact in the cow-calf sector of the southern Great Plains. There are several management strategies that have been shown to positively impact efficiency including, but not limited to, monensin supplementation, limit feeding, hay feeder design, and ammoniation. It is not clear, however, what level of improved hay feeding efficiency these strategies could have when combined.

Ammonation

With a low-quality roughage diet, voluntary food intake is a major factor influencing animal performance (Zorrilla-Rios et al., 1985). Supplying the proper nutrients for metabolic function of ruminant animals is critical for animal maintenance and production. Productivity of ruminants on low-quality forages may be limited by deficiencies of ruminally available nitrogen (N) or energy (Vagnoni et al., 1995). Two procedures can increase the consumption of low quality roughages: 1) physical processing and 2) chemical treatment (Zorrilla-Rios et al., 1991a). These processes increase consumption by increasing particle passage rate in the rumen. Ammoniation of low-quality forages increases intake through chemical effects on the forage or by increasing crude protein (CP) content of the forage (Zorrilla-Rios et al., 1991a) to improve animal performance over that of animals consuming untreated low-quality forage.

Ammoniation of low-quality forages can be accomplished by adding anhydrous ammonia (NH_3) in an air tight container or environment. This is accomplished with a stack of hay covered with a large 6 mm polyethylene plastic sheet that has gravel or dirt piled along the edges to seal the stack. Once the bale or stack of bales is covered NH_3 (2-3% of hay DM) is released into the container. The stack is left undisturbed for a number of weeks, depending on ambient temperature, to allow the chemical reactions within the stack to take place. Ammoniation has been shown to decrease neutral detergent fiber (NDF) and hemicellulose while increasing CP (Saenger et al., 1983; Wyatt et al., 1989; Zorrilla-Rios et al., 1991a). Saenger et al. (1983) found no differences for CP or in vitro dry matter disappearance of ammoniated hay that was found on the side of the stack or along the length of the stack, suggesting that ammoniation can create uniform results along the length and width of a stack. However, there was a difference found between the top and the bottom, possibly due to increased moisture along the top due to evaporation. The forage typically changes to a caramel color (Saenger et al,. 1983) and increases in fragility (Vagnoni et al., 1995). Zorrilla-Rios et al. (1985) found that fragility of wheat straw increased by almost 17% measured by the amount of hay passing through a 1mm screen during grinding. This suggests that ammoniation allows for greater mechanical degradation by the animal, resulting in reduced particle size and faster rumination.

Wheat straw CP has been reported to increase after ammoniation by 3.8 percentage units (Zorrilla-Rios et al., 1991b) and 7.6 percentage units (Saenger et al., 1983). Additionally, Gates et al. (1987) reported a significant increase in CP of indiangrass and switchgrass of different maturity levels by an average increase of 7 percentage units. Nitrogen retention after ammoniation is variable due to differences in weather and ammoniation methods. Retention of N was reported as 57% (Beuttner et al., 1982), 43% (Zorrilla-Rios et al., 1991a), 18% or 21% (Zorrilla-Rios et al., 1991b) and 67% (Grotheer et al., 1985). Ammoniation of bermudagrass hay increased fiber component digestibility by 31.1%, 23.7%, and 33.6% for NDF, acid detergent fiber (ADF) and hemicelluloses, respectively, which is supported by Gates et al. (1987) as cited by Wyatt et al. (1989) who found an increase in digestibility of all fiber components except lignin due to ammoniation of warm season grass. A relatively high percentage of retained N is thought to be available for microbial utilization. Of the 48% capture of N in ammoniated bermudagrass hay, 7.8 and 25% were associated with the ADF and NDF fractions respectively. Thus, the majority of the added N presumably was available for microbial utilization (Vagnoni et al., 1995). In a second experiment performed by Vagnoni et al. (1995) lower ruminal NH_3N concentrations were found after feeding ammoniated hay than urea to ruminally cannulated steers, which suggests that the N from ammoniated hay is of greater value to microbial protein synthesis and is of greater value than N from urea supplementation.

Yearling steers observed an increase in average daily gain (ADG) of 0.14 kg/d by consuming ammoniated bermudagrass hay (Vagnoni et al., 1995). Studies that showed similar ADG response to consumption of ammoniated hay include Moore et al. (1981) and Wyatt et al. (1987), with increases of 0.16 and 0.14 kg, respectively. Experiment 2 by Zorrilla-Rios et al.

(1991b) showed that steers consuming ammoniated wheat straw increased ADG from 0.059 kg/d to 0.377 kg/d while increasing intake 9.2%. Experiment 1 from the same study demonstrated that ammoniated straw produced weight gains that were similar to untreated straw plus 500 g/d of soybean meal. Saenger et al. (1983) reported similar findings with growing heifers increasing intake by 29.5% over non ammoniated hay. This increased intake is not considered a result of correcting N deficiency; both diets were isonitrogenous, therefore, the increase in intake is thought to be due to an increase in digestibility resulting from altering the NDF, ADF, and hemicellulose fractions and digestibility of these fractions of the straw. These findings have been supported by Saenger et al. (1982) when feeding ammoniated cornstalks. Wyatt et al. (1989) found an increase in intake when feeding ammoniated bermudagrass hay, but noticed that heifers from both treatments consumed to a common NDF consumption. Similar results were reported by Vagnoni et al. (1995) when comparing NDF intake by cattle across 6 diets, they suggested that their findings of cattle consuming 1.14% BW/d of NDF is in accordance with the theory proposed by (Mertens, 1992) that dietary consumption ceases at 1.2% BW/d of NDF. This may suggest that the increase in NDF digestibility allows for increased intake in cattle consuming ammoniated hay.

Volatile fatty acids (VFA) are produced in the rumen as a byproduct of microbial fermentation. Volatile fatty acids are absorbed across the ruminal epithelium and are then converted and used as energy throughout the body. Volatile fatty acids found in the largest concentrations in the rumen of beef cattle are Acetate, Butyrate, and propionate. Acetate is found in the highest ratio among the 3 when high roughage diets are being consumed. As the diets increase in levels of concentrate the ratio of propionate increases relative to acetate. Butyrate levels tend to remain fairly constant. Propionate is the most energy efficient therefore in a ruminant feeding system the lower the acetate:propionate ratio the higher the performance.

Cannulated steers were fed ammoniated berumdagrass hay compared to non-ammoniated hay resulting in no significant increase in total VFA concentrations, or a change in acetate:propionate ratio (Vagnoni et al., 1995). However, it was discussed that concentrations and not total production of VFA was measured, so it is not known if differences in rate of fluid passage or absorption across the ruminal wall could have accounted for no difference in VFA concentrations when ammoniated hay was fed (Vagnoni et al., 1995). In contrast, Wyatt et al. (1989) found an increase in total VFA production from 78.8Mm to 92.3Mm for untreated hay and ammoniated hay, respectively. The results from Vagnoni et al. (1995) and Wyatt et al. (1989) found an increase in VFA production but no change in the molar ratio of VFA in the rumen.

Monensin

Monensin is a biologically active compound produced by *Streptomyces cinnamonensis* (Clanton et al., 1981) with 3 primary modes of action 1) improved efficiency of energy metabolism in the rumen, 2) improved N metabolism in the rumen, and 3) reduction of metabolic disorders, especially lactic acidosis and bloat. Chalupa (1979) and Sankaram et al. (1985) as cited by Bretschneider et al. (2008) stated that ionophores disrupt the bacterial permeability barrier by enhancing the trans-membrane cation transport. It is this mode of action that alters the microbial population of the rumen. Gram negative bacteria produce higher proportions of propionate. Monensin increases the metabolizable energy content from a feed theoretically by increasing the ratio of propionate to acetate and butyrate produced in the rumen and thereby diverting energy from methane to propionate (Lemenager et al., 1978). Additionally, the absence of large amounts of lactate producing bacteria such as *Streptococcus bovis* even when high starch rations are consumed results in the reduction of metabolic disorders.

Ionophores such as monensin have been show to exert their influence on beef cow weight gain and feed efficiency without any detrimental effect on other measures of performance such as fertility and milk production (Sprott et al., 1988). Forage quality tends to influence the effect of monensin on ADG of beef cattle; as forage quality increases net ADG response decreases (Bretschneider et al., 2008). In a review by Bretschneider et al. (2008) it was concluded that ADG increased quadratically with increasing doses of monensin and feed conversion was also quadratically increased without affecting DMI. Clanton et al. (1981) reported a 10% feed savings when monensin was provided at 200 or 300 mg/hd daily with no reduction in performance when cows were fed medium to high-quality hay. In contrast Clanton et al. (1981) in a second experiment found no differences in cow performance when intake of a corn silage based ration was held constant. Ellis et al. (1984) as cited by Bretschneider et al. (2008) proposed that on high-quality pastures cattle have a reduced response to monensin, mainly because under this feeding regime, they reach their upper genetic limit for weight gain. However, grazing high-quality pastures may result in higher levels of propionate, reducing the effect of monensin. Cows grazing native range and being fed monensin at 0, 50, or 200 mg/hd daily demonstrated a decrease in forage intake as monensin increased while cow performance was similar between the control and 200 mg of monensin (Lemenager et al., 1978). Conversely, Bretschneider et al. (2008) reported that daily doses of monensin between 0 and 140 mg/100kg of BW did not show any significant ($P > 0.1$) effect, either linear or quadratic on DMI and that the use of ionophores with high inclusion of forages would not affect the DMI.

Ionophores tend to improve ADG and feed conversion without changing DMI, suggesting that improvements in beef cattle performance may be related to a decrease in the acetate:propionate ratio (Bretschneider et al., 2008). Walker et al. (1980) found that inclusion of monensin at 50, 100, and 200 mg/d decreased the acetate:propionate ratio when beef cows were fed a corn silage diet. Burrell (1977) as cited by Sprott et al. (1988) reported that cows in body condition of less than 4, on a 9-point system, showed no weight gain response to monensin supplementation which demonstrates the importance of body condition to weight gain when supplementing monensin. The literature on monensin supplementation does not reveal a clear response in weight gain and feed conversion, likely due to the broad array of experimental designs, which emphasizes the need for research to elucidate the interaction between forage quality and performance of ionophore fed cattle (Bretschneider et al., 2008). When feeding low quality hay, ionophores such as monensin show the ability to either reduce intake while maintaining performance (Clanton et al., 1981; Lemenager et al., 1978) or increase ADG while not increasing DMI (Clanton et al., 1981; Bretschneider et al., 2008), and with proper management can result in a significant economic benefit due to increased overall hay feeding efficiency.

Monensin supplementation paired with ammoniation of hay may not be completely additive. Heifers consuming either ammoniated or non-ammoniated hay with a monensin supplement showed a low growth response, increased rumen ammonia concentrations, and less reduction in the acetate:propionate ratio in heifers consuming ammoniated hay along with monensin (Wyatt et al., 1989). Experiment 1 of Vagnoni et al. (1995) reported no increase in ADG of steers receiving ammoniated hay and monensin over steers receiving only ammoniated hay. Additionally monensin supplementation reduced intake as a percent of BW in untreated hay, but no effect on intake was observed when monensin was included with ammoniated hay. In the in situ portion of the study, contrary to Wyatt et al. (1989) the acetate:propionate ratio was decreased by monensin supplementation for both treated and untreated hay (Vagnoni 1995). Wyatt et al. (1989) reported a significant 37% increase in intake by heifers consuming monensin and untreated hay, but no difference by heifers consuming monensin and ammoniated hay. In this study cattle were consuming natural protein vs. higher levels of NPN. Hansen and Klopfenstein (1979) fed growing steers either NPN or natural protein along with 0 or 200 mg/hd daily monensin and found an improved gain by steers receiving monensin and natural protein, but no increase in gain with steers receiving NPN and monensin.

Limit Feeding

Limit feeding a ration or commodity to cattle is a common management strategy. Limit feeding is most commonly applied in two ways 1) cattle are fed once or multiple times daily with only the amount desired for consumption or 2) cattle are allowed access to a larger amount of feed only for a period long enough to allow for the desired consumption. This strategy is often used to control cow performance, manage feed disappearance or both. It is thought that limiting access to feed such as round bales of hay has the potential to reduce intake while maintaining a desired level of cow performance. Loerch (1996), as cited by Miller et al. (2007), stated that ad libitum hay feeding is one of the most common methods of supplementing nutrients; however, it can be $1.50 more per head per day than limit feeding. There is very little information in the literature dealing directly with limit feeding hay to cattle. A paper published by Miller et al. (2007) conducted 2 experiments investigating the effects of restricting time of access to round bales of hay. In experiment 1, alfalfa hay was placed in a feeder and cattle were given 3 hours, 6 hours, 9 hours, and ad libitum access to the hay (Miller et al., 2007). Cow BW gain increased linearly (54, 73, 87 and 94 kg) and quadratically as time of access to hay increased. Additionally, the cattle with only 3 hours access gained weight (54 kg) and maintained body condition (5.8) at an acceptable level (Miller et al., 2007). Miller et al. (2007) reported a linear increase in waste as access increased and a linear decrease in intake as access decreased. These results indicate that hay feeding efficiency can be increased by limiting access to good quality hay by limiting intake and total waste while maintaining an acceptable level of cow performance.

Bale Feeder Type

There are many ways that producers can feed round bales ranging from simply placing a bale directly on the ground to mechanically processing the bale and placing it in a feed bunk.

Landbolm et al. (2007) stated that feeding hay in a tapered cone feeder was more economical than unrolling bales and using a bale processor, and reported wintering costs of $100, $109, and $127, respectively. One of the most common methods is to place the bale in a round bale feeder. Feeders vary greatly in design and effectiveness. Buskirk et al. (2003) conducted a study comparing 4 feeder types including 2 ring feeders and 2 rectangular feeders. Hay waste was significantly affected by feeder type with hay waste as a percent of hay disappearance reported as 14.6, 11.4, 6.1, and 3.5% for the cradle feeder, trailer feeder, ring feeder, and cone feeder, respectively. These results are supported by Comerford et al. (1994) who reported similar results of a cone feeder reducing hay waste from 8% to 1.9%. There is a wide range of reported hay losses, ranging from 1.9% (Comerford et al., 1994) to 20 to 30% (Belyea et al., 1995; Baxter et al., 1986) as cited by Buskirk et al. (2003). Feeder design has been shown to alter cow behavior and interaction while feeding. Hay waste was reduced for feeders that had feeding stations, top rails that encouraged reaching and feeders that had feeding stations in a circular orientation rather than a linear orientation (Buskirk et al., 2003). Agnostic interactions and frequency of entrances to the feeder were greatly increased with the cradle feeder (30.7/h) compared to other feeders (10.9, 7.4,13.6/h for cone, ring, and trailer feeders, respectively) (Buskirk et al., 2003). Behavioral interactions combined with cow competition and flight zone differences among feeders suggest that a major factor in the improvement of hay feeding efficiency was reduced aggressive interactions among the cows (Buskirk et al., 2003). There is a wide range of hay waste due to feeder type in the current literature, however much variation could possibly be associated with factors such as weather, stocking rate, bale size, and quality of hay fed. Regardless of other variables, it is clear that feeder type has great potential for increasing hay feeding efficiency.

Summary

The literature shows that there is great potential for use of simple management technologies to increase hay feeding efficiency. There has been very little research, however, that investigates the effect on total system efficiency when several of these technologies are combined. More research is needed to investigate the potential to increase efficiency in the beef cow herd with the combination of multiple factors such as ammoniation, monensin supplementation, limit feeding, and type of bale feeders.

LITERATURE CITED

Baxter, H. D., B. L. Bledsoe, M. J. Montgomery, and J. R. Owen. 1986. Comparison of alfalfa-orchardgrass hay stored in large round bales and conventional rectangular bales for lactating cows. J. Dairy Sci. 69:1854-1864.

Belyea, R. L., F. A. Martz, and S. Bell. 1985. Storage and feeding losses of large round bales. J. Dairy Sci. 68:3371-3375.

Bretschneider, G., J. C. Elizalde and F. A. Perez. 2008. The effect of feeding antibiotic growth promoters on the performance of beef cattle consuming forage based diets: a review. Livest. Sci. 114:135-149.

Buettner, M. R., Lechtenberg, K. S. Hendrix and J. M Hertel. 1982. Composition and digestion of ammoniated tall fescue (*Festuca arundinacea schreb*.) hay. J. Anim. Sci. 54:173-178.

Burrell W. C. 1977. The effect of monensin in lactating beef cows in poor body condition receiving low levels of energy. PhD. Dissertation. Texas A&M Univ., College Station.

Buskirk, D. D., A. J. Zanella, T. M. Harrigan, J. L. Van Lente, L. M. Gnagey and M. J. Kaercher. 2003. Large round bale feeder design affects hay utilization and beef cow behavior. J. Anim. Sci. 81:109-115.

Chalupa, W. 1979. Chemical control of rumen microbial metabolism. In: Digestive Physiology and Metabolism in Ruminants. In: Ruckebusch, Y., Thivend, P. (Eds.), Proc. Fifth International Symposium on Ruminant Physiology. Cleremont-Ferrand, pp. 325-347.

Clanton, D. C., M. E. England and J. C. Parrott III. 1981. Effect of Monensin on efficiency of production in beef cows. J. Anim. Sci. 53:873-880.

Comerford, J. W., D. R. Buckmaster, and E. H. Cash. 1994. Effects of three storage methods on nutrient losses from harvest, storage and feeding of large bales. J. Anim. Sci. 72(Suppl. 2):130(Abstr.).

Ellis, W. C., Horn, G. W., Delaney, D., Pond, K. R., 1984. Effects of ionophores on grazed forage utilization and their economic value for cattle on wheat pasture. In: Horn, G. W. (Ed.), Proc. Nat. Wheat Pasture Sypm. Oklahoma State University, pp. 343-355. MP-115.

Gates, R. N., T. J. Klopfenstein, S. S. Waller, W. W. Stroup, R. A. Britton and B. F. Anderson. 1987. Influence of thermo-ammoniation on quality of warm-season grass hay for steers. J. Anim. Sci. 64:1821-1834.

Grotheer, M. D., D. L. Cross, L. W. Grimes, W. J. Caldwell and L. J. Johnson. 1985. Effect of moisture level and injection of ammonia on nutrient quality and preservation of coastal berumdagrass hay. J. Anim. Sci. 61:1370.

Hanson, T. L., and T. Klopfenstein. 1979. Monensin, protein source and protein levels for growing steers. J. Anim. Sci. 48:474.

Landbolm, D. G., G. P. Lardy, R. Fast, C. J. Wachenheim, and T. S. Petry. 2007. Effect of hay feeding methods on cow performance, hay waste, and wintering cost. Prof. Anim. Sci. 23:246-252.

Loerch, S. C. 1996. Limit feeding corn as an alternative to hay for gestating beef cows. J. Anim. Sci. 74:1211

Lemenager, R. P., F. N. Owens, K. S. Lusby and R. Totusek. 1978. Monensin, forage intake and lactation of range beef cows. J. Anim. Sci. 47:247-254.

Mertens, D. R. 1992. Nonstructural and structural carbohydrates. In: H. H. Van Horn and C. J. Wilcox (Ed.) Large Dairy Herd Management. Pp 219-235. Am Dairy Sci. Assoc., Champaign, IL.

Miller, A. J., D. B. Faulkner, R. K. Knipe, D. R. Strohbehn, D.F. Parrett, and L.L. Berger. 2001. Critical control points for profitability in the cow-calf enterprise. Prof. Anim. Sci. 17:95-302.

Miller, A. J., D. B. Faulkner, T. C. Cunningham, and J. M. Dahlquist. 2007. Restricting time of access to large round bales of hay affects hay waste and cow performance. Prof. Anim. Sci. 23:366-372.

Moore, K. J., V. L. Lechtenberg, K. S. Hendrix, and J. M. Hertel. 1981. Improving hay quality by ammoniation. In: Proc. 14th Int. Grassl. Conf. Lexington, KY. Pp 626-628. Westview Press, Boulder, CO.

Saenger, P. F., R. P. Lemenager and K. S. Hendrix. 1982. Anhydrous ammonia treatment of corn stover and its effects on digestibility intake and performance of beef cattle. J. Anim. Sci. 54:419.

Saenger, P. F., R. P. Lemenager and K. S. Hendrix. 1983. Effects of anhydrous ammonia treatment of wheat straw upon in vitro digestion, performance and intake by beef cattle. J. Anim. Sci. 56:15-20.

Sankaram, M.E., Shastri, B.P., Easwaran, K.R.K. 1985. Mechanisms of transmembrane cation transport studied by nuclear magnetic resonance spectroscopy. Proc. Int. Symp. Biomol. Struct. Interactions, Suppl. J. Biosci. 8:343-354.

Sprott L. R., T. B. Goehring, J. R. Beverly and L. R. Corah. 1988. Effects of Ionophores on cow herd production: a review. J. Anim. Sci. 66:1340-1346.

Vagnoni, D. B., W. M. Craig, R. N. Gates, W. E. Wyatt and L. L. Southern. 1995. Monensin and ammoniation or urea supplementation of bermudagrass hay diets for steers. J. Anim. Sci. 73:1793-1802.

Vestal, M., W. clement, D. Doye, D. Lalman. 2007. Cow-calf production practices in Oklahoma part 1. http://agecon.okstate.edu/faculty/publications/2814.pdf. Accessed April 10, 2013.

Walker, P. M., B. A. Weichenthal and G. F. Cmarik. 1980. Efficacy of monensin for beef cows. J. Anim. Sci. 51:532.

Wyatt, W. E., W. M. Craig, R. N. Gates, F. G. Hembry and D. L. Thompson, Jr. 1989. Effects of ammoniated berumdagrass hay and monensin supplementation on heifer postweaning growth. J. Anim. Sci. 68:1698-1706.

Zorrilla-Rios, J., G. W. Horn, R. W. McNew. 1991a. Nutritive value of ammoniated wheat straw fed to cattle. J. Anim. Sci. 69:283-294.

Zorrilla-Rios, J., G. W. Horn, W. A. Phillips, and R.W. McNew. 1991b. Energy and protein supplementation of ammoniated wheat straw diets for growing steers. J. Anim. Sci. 69:1809-1819.

Zorrilla-Rios, J., F. N. Owens, G. W. Horn and R. W. McNew. 1985. Effect of ammoniation of wheat straw on performance and digestion kinetics in cattle. J. Anim. Sci. 60:184.

CHAPTER III

EFFECTS OF BALE FEEDER TYPE, MONENSIN SUPPLEMENTATION, AND LIMIT FEEDING ON HAY WASTE, INTAKE, AND PERFORMANCE OF BEEF COWS

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ABSTRACT

This experiment was conducted to evaluate the effects of limit feeding, monensin supplementation, and bale feeder type on cow performance, hay waste, net disappearance, and apparent digestibility. Angus and Angus X Hereford cows (n = 72; 532 ± 59 kg) were allotted by BW and assigned to one of two treatments. Treatment 1 (CONT; control) included ad libitum access to a steel ring feeder and 0.45 kg/d of a 38% CP cottonseed meal based supplement. Treatment 2 (LIMIT; limited) included 7 h access to a modified cone feeder with low quality prairie hay and 0.45 kg/d of a 38% CP cottonseed meal based supplement with 200 mg/hd inclusion of monensin (MON). Cows were allotted to one of four previously grazed 1.0 ha paddocks with a 12.2 x 7.6 m^2 concrete pad. There was no difference (*P* = 0.41) between d 0 and off test BW change for cows receiving the CONT or LIMIT treatment. Hay waste was reduced (*P* = 0.01) by the LIMIT treatment. There was a reduction (*P* = 0.01) in percent of bale weight wasted with the LIMIT treatment wasting 11.9%, compared to 24.9% in the CONT treatment. Net disappearance of hay/d for each cow was reduced from (*P* = 0.03) 12.04 to 9.96 kg for the CONT and LIMIT treatments, respectively. Improved hay efficiency resulted in a decrease in cost of hay and supplement/cow of $0.32/d.

Key Words: beef cattle, hay waste, feeder design, monensin

INTRODUCTION

Feeding hay to beef cattle in the Great Plains is a very common practice. There have been several technologies or management strategies developed to increase efficiency of beef cattle consuming forage, or harvested forage such as hay. These include, but are not limited to, hay feeder design, limiting access to hay, and monensin supplementation. Feed for cattle can account for over 60% of the costs of a cow-calf operation (Miller et al., 2001). For 101 northern plains beef herds hay cost averaged $152 per cow exposed (Hughes, 2013). As input costs continue to rise, the ability to reduce feed costs by increasing hay feeding efficiency has the potential to greatly affect cow-calf profitability in the Great Plains.

Bale feeder type greatly affects the efficiency of hay feeding. Buskirk et al. (2003) observed ranges in waste as a percent of hay disappearance from 3.5 to 14.6% due to bale feeder type. Sexten et al. (2011) reported low efficiency feeders can waste up to 21.5% of a bale of hay. In the same study, Sexten et al. (2011) found that hay waste can be reduced by 74% by using a high efficiency feeder compared to a conventional ring feeder.

Limiting access to hay is an effective method to decrease hay waste. Hay waste increases linearly as time of access increases (Miller et al., 2007). Depending on the quality of hay fed, limit feeding gives producers the ability to maintain acceptable cow performance while reducing the amount of hay wasted and consumed.

Supplementing beef cattle diets with monensin (MON) can potentially reduce the amount of hay needed to maintain cow performance by increasing efficiency of energy and nitrogen metabolism in the rumen (Clanton et al., 1981). Supplementing beef cow diets with MON has the potential to increase average daily gain (ADG) and increase feed conversion without affecting dry matter intake (DMI) (Bretschneider et al., 2008). The increase in efficiency of utilization of forage by cattle consuming MON can result in maintaining desired performance while decreasing forage intake. Lemenager et al. (1978) observed that MON supplementation (200 mg/hd/day) decreased DMI without affecting cow performance. Similar results were reported by Clanton et al. (1981), with a 10% feed savings and no difference in cow performance when MON was fed at 200 or 300 mg/hd daily.

While these individual technologies have been shown to improve forage use efficiency, the impact of incorporating all three in a winter feeding system has not been documented. Therefore, the purpose of this study was to determine hay disappearance, hay waste, and animal performance in a winter feeding system integrating these three technologies compared to a more conventional winter feeding system.

MATERIALS AND METHODS

Animals and Diet

This experiment was conducted at the Range Cow Research Center, North Range Unit, located approximately 16 km west of Stillwater, OK. All experimental protocols were approved by Oklahoma State University Animal Care and Use Committee. Seventy-two gestating Angus and Angus x Hereford cows (532 ± 59 kg; BCS = 4.41 ± 0.80) were allotted by 12 h shrunk BW and assigned to one of two treatments. Treatment 1 (CONT; control) included ad libitum access to a steel ring feeder containing low quality prairie hay (6.2% CP, 54% TDN) and 0.45 kg/d of a 38% CP cottonseed meal based supplement. Treatment 2 (LIMIT; limited) included limited access to a modified cone feeder containing low quality prairie hay (6.2% CP, 54% TDN) and 0.45 kg/d of a 38% CP cottonseed meal based supplement with 200 mg/d per head inclusion of monensin (MON, Rumensin 90®; Elanco Animal Health; Greenfield, IN) Wire panels were placed around the concrete pads to allow access for 7 h daily; starting at 0800 h. Cows were assigned to one of six pens measuring two acres each, and three replications (pens) per treatment. Each pen was previously grazed to remove standing forage and four pens included a 12.2 x 7.6

m^2 concrete pad. Supplementation and hay feeding began September 25, 2012 (d 0) and ended December 15, 2012 (d 84).

Waste Collection

Three waste collection periods were completed during the experiment. Collections were only completed on the four pens containing a cement pad. Waste collection periods are defined as the time required for a pen to consume 85% of a bale of hay. Prior to collection, the cement pads were cleared of hay and debris, and all hay remaining within the feeders was removed, weighed, and sampled. All hay removed from within the feeders was sampled and weighed to later calculate estimated intake and net disappearance for the 84 d trial. Initiation of the collection period began when a fresh round bale was placed in each feeder. The bale was weighed and core sampled prior to being placed into the feeder. Hay waste was considered any hay that was found outside of the feeder. Most fecal material was removed from the collection pad. Hay was separated into contaminated and dry subgroups. Each subgroup was sampled and weight was adjusted for DM content. Contaminated hay waste was considered any hay that had fecal material, urine, or any precipitation that affected the DM content of the waste. Dry hay waste was any hay that was not highly contaminated. Hay waste was measured at 1400 h daily until 85% of the hay within each feeder was consumed. Cow intake was not limited at any point in the experiment. When 85% of hay was consumed all remaining hay within the feeder was removed, weighed, sampled, and a new bale was placed in each feeder. All hay waste and orts were discarded after sampling. After hay was collected, it was weighed on a portable scale and sampled for further analysis. Fecal samples were taken daily during the collection period at 0700 h and 1800 h. Twelve fecal grab samples were taken per pen each d of collection. Six random fresh samples were taken by hand within each pen per collection.

Cow Measurements

Cows were weighed and allotted based on allotment BW. The following day cows were weighed again (d 0) and placed on treatment. A BW and BCS (1 to 9 scale; Wagner et al., 1988) was recorded on all cows on d 0, d 56, d 84, and a final 12 hour shrunk weight (Off test weight) was taken on December 20, 2012. Off test weights were taken to account for fill differences due to limit feeding by comingling all cows in a common pasture and shrunk overnight with access to water before being weighed. On weigh d, cows on the CONT treatments were moved at daylight and comingled with cows in LIMIT pens where there was not access to hay. This was done to minimize fill differences due to hay intake immediately prior to collecting weights. Cows had full access to automatic frost proof water tanks as well as ad libitum access to mineral. Total hay fed and orts were summed between d 0 and d 84. Net disappearance is defined as orts subtracted from total hay fed.

Chemical Analysis

All fecal samples and hay samples were oven dried at 50°C and DM was calculated on all hay samples. Dried samples were ground using a Wiley Mill (Model 4, Thomas Scienctific, Sweedesboro, NJ). Fecal samples were ground through a 1mm screen, all hay samples were ground through a 2mm screen. Contaminated waste, dry waste, orts, and fecals were composited within pen, per collection period. Bale cores were composited within pen. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined using an ANKOM Fiber Analyzer (ANKOM Technology, 2005). Nitrogen content of the samples was determined using a Leco NS-2000 Nitrogen Analyzer (Leco Corporation, St. Joseph, MI). Apparent digestibility was calculated using acid detergent insoluble ash (ADIA).

Economics

Economics of the trial were calculated by using current prices of materials and inputs at the initiation of the study. Feed, hay, feeders, and fence supplies used were representative of prices found in Oklahoma during the winter of 2012- 2013. Bale feeder prices were calculated using a five year depreciation schedule assuming no salvage value. Fence materials were calculated using a three year depreciation schedule with no salvage value. Sensitivity was performed using differences in prices of hay and length of feeding period. Economic benefit is reported as total savings per head per day.

Statistical Analysis

Data were analyzed using the MIXED procedure of SAS (SAS Inst., Inc., Cary, NC). Pen was considered the experimental unit and the model included treatment as a fixed effect and collection period as a random effect. For all analyses, when the *P*-Value for the F-Statistic was ≤ 0.05, least square means were separated and reported. Tendencies were reported at 0.05 < P-Value ≤ 0.10.

RESULTS AND DISCUSSION

Cow Performance

There was no difference between treatments for d 0-84 BW change (*P* = 0.33; Table 3.1), d 0-84 BCS (*P* = 0.28; Table 3.2) and off test BW (*P* = 0.86). Additionally, there was no difference in d 84 BW (*P* = 0.94) or d 84 BCS (*P* = 0.92) for cows receiving either treatment. Cows receiving both treatments lost BW between d 0 and off test BW, but gained weight between d 0 and d 84. Cows receiving LIMIT treatment lost 6.4 kg while cows receiving CONT treatment lost 10.9 kg between d 0 and off test BW. There was a tendency for cow BW change (*P* =0.10) and cow BCS (*P* = 0.08) on d 0-28 to be different between treatments, with cows receiving the

CONT treatment to gain more BW and BCS than cows receiving LIMIT treatment. This was expected as cows consuming the LIMIT treatment were only allowed access to hay 7 h/d, resulting in less gut fill than cows consuming the CONT treatment with ad libitum access to hay. The cows receiving the LIMIT treatment were visibly less full than cows receiving the CONT treatment. It was noted, however, that cows receiving the LIMIT treatment gained more BW (P = 0.01) and BCS (P = 0.02) than cows receiving the CONT for d 56-84. Diets were designed to meet protein requirements of gestating beef cows. It was expected that cows on both treatments would lose weight due to the low quality of the prairie hay. These results suggest that there was no significant difference in cow performance between d 0 and d 87 due to differences in treatment. The results from this study are supported by Miller et al. (2007) who found that cattle with limited access to hay were able to maintain acceptable levels of weight gain and BCS. Monensin supplementation has resulted in feed savings of 10% with no reduction in performance when cattle were fed medium to high quality hay (Clanton et al., 1981). In contrast, Bretschneider et al. (2008) found that monensin inclusion did not affect DMI. Limiting access to cows on the LIMIT treatment was designed to reduce their DMI. It was predicted, however, that the inclusion of MON in the supplement would increase the efficiency of utilization of the hay consumed, resulting in no difference in cow performance. The cow performance of this study suggests that increased efficiency of hay consumed due to MON supplementation and limit feeding may have allowed cows receiving the LIMIT treatment to maintain performance on less hay than cows receiving the CONT treatment.

Hay Waste

There was no differences observed in orts (P = 0.14; Table 3.3) or initial bale weight (P = 0.89) between treatments during the waste collection periods. Cows receiving the CONT treatment had a significantly larger (P < 0.01) amount of contaminated waste, dry waste, and total waste than cows receiving the LIMIT treatment. Total hay waste was reduced by the LIMIT treatment by 82 kg per bale fed. Cows receiving the CONT treatment wasted 157 kg, while cows receiving the LIMIT treatment wasted only 75 kg. This data is similar to findings from Miller et al. (2007), who found a linear increase in hay waste as time of access increased. Difference in percent of bale weight wasted was highly significant ($P \leq 0.01$) between treatments. Cows receiving the CONT treatment wasted 24.9% of bale weight, while cows receiving the CONT treatment wasted only 11.9% of bale weight. Differences in hay waste are shown in figure 1. There is a visually significant larger amount of hay waste around the feeder in the CONT treatment than the LIMIT treatment. The modified cone feeder supports the bale above the cows heads, making the cows pick smaller amounts of hay from the bale. When the bale becomes eaten down however, the modified cone feeder shows no advantage, becoming no different than the ring feeder in design when the hay is at or below the sheeted bottom. The waste numbers in this data are higher than those reported in similar studies (Buskirk et al., 2003; Sexten et al., 2011); however, there have been large ranges of hay waste reported. The range across studies in bale feeder types have resulted in reported hay waste between 1.9% (Comerford et al., 1994) to 30% (Belyea et al., 1995). The results of these data suggest that the combination of technologies in the LIMIT treatment are an effective method in reducing hay waste, resulting in a decrease in total waste of 52%.

Net Disappearance and Intake

Net disappearance, calculated by subtracting orts from hay fed, was significantly different ($P \leq 0.03$; Table 3.4) between treatments when expressed on a per pen, per cow, or per cow/d basis. Hay disappearance per cow was 2.08 kg/d less for cows receiving the LIMIT treatment. Daily net disappearance per cow was 12.04 kg for the CONT treatment, compared to 9.96 kg for the LIMIT treatment. Hay disappearance per cow for the LIMIT treatment between d 0 and d 87 was 837 kg, compared to 1,012 kg for the CONT treatment. Total hay savings due to the combination of technologies in the LIMIT treatment for the entire experiment (87 d) per pen (n = 12) was 2,097 kg. Net disappearance is a function of both cow intake and hay waste, which makes it an effective indicator of hay feeding efficiency. Intake was estimated for each collection period, lasting between 3 and 5 days. Orts and total waste were subtracted from total hay fed to calculate estimated intake. Cows receiving the LIMIT treatment consumed less hay on a per pen/d basis($P < 0.01$; Table 3.5) or a per cow/d basis ($P < 0.01$). Cows receiving the CONT treatment consumed 8.62 kg/d of prairie hay, compared to only 7.30 kg/d of prairie hay for the cows receiving the LIMIT treatment. The combination of modified cone feeder, limit feeding, and MON supplementation in the LIMIT treatment was an effective method to reduce net disappearance and intake, resulting in improved hay feeding efficiency.

Apparent Digestibility

The effects of bale feeder type, MON supplementation, and limit feeding on apparent digestibility are shown in table 3.5. There was no difference ($P > 0.21$) in DM, NDF, ADF and OM total tract apparent digestibility between treatments. There was, however, a numerical decrease observed in DM, NDF, ADF, and OM total tract digestibility in cows receiving the LIMIT treatment. In a similar study Sexten et al. (2011) observed an increase ($P < 0.05$) in apparent digestibility in cows receiving MON supplementation, while there was no difference due to feeder type.

Economics

Costs associated with each treatment are different due to differences in overhead cost and daily costs. Overhead costs for this study are referred to as bale feeder and fence costs. These costs are depreciated for five years for the bale feeder and three years for the fencing materials. The modified cone feeder in the LIMIT treatment costs $575 dollars, compared to $455 for the ring feeder. The yearly cost for the feeders is shown in table 3.6. The largest difference in cost between treatments is the cost of the fence. To limit access in the paddocks for this experiment a fence requiring five t-posts and 6 cattle panels was used. This resulted in an additional $45.33 of overhead for the LIMIT treatment. Hay cost and supplement cost for the economics of table 3.6 was 100 and 403 $/ton, respectively. The daily costs are presented on a per cow/d basis (table 3.6). Total cost was found by dividing overhead costs by the number of cows per feeder, and multiplying number of days by the daily cost. The LIMIT treatment resulted in a decrease in net disappearance, which resulted in a decreased hay cost of $0.21/d. Overall, the cost/d of the CONT and LIMIT treatment was $1.56 and $1.43, respectively, per cow. Total cost for the CONT treatment (84 d, 12 hd/pen) was $136.00. The LIMIT treatment reduced the cost for the same period to $124.19. The economic sensitivity to hay price and length of feeding period can be seen in table 3.7. Cheap hay prices combined with a short feeding period result in no benefit of the combination of technologies in the LIMIT treatment. The LIMIT treatment does show substantial economic benefit as hay price increases up to $200/ton and length of feeding approaches 120 d.

General Discussion

This experiment used stacked hay feeding efficiency technologies in a systems approach to determine the possible reduction in hay waste while maintaining cow performance. During the feeding period cow BW change was not different between treatments. Cattle receiving the LIMIT treatment were given less access to hay, but were able to utilize the hay available to them at a high enough level of efficiency to maintain performance during ad libitum access. The LIMIT treatment also resulted in significantly less total hay waste, and less net disappearance. The experimental design of the experiment does not allow results to be attributed to any single factor used. In a similar study Sexten et al. (2011) observed an increase in cow BW gain when MON was fed and a decrease in hay waste when high efficiency bale feeders were used. Because of this weight gain response, we hypothesized that reducing access to hay would not only reduce hay waste, but would reduce intake slightly without sacrificing cow performance. The ability to decrease the amount of hay fed to beef cattle could potentially have positive economic benefits to cow-calf producers. This experiment resulted in a savings of $11.80 per cow over an 84 d feeding period. This experiment used a density of 12 cows per feeder. In a similar system it was estimated that a density of up to 15 cows per feeder could be used with no negative impacts on hay waste or cow performance. The overhead cost of fence and bale feeders was an important cost in the sensitivity analysis, so the density of 15 cows per feeder was reported as optimum density, as shown in table 3.7. As hay prices and days in the feeding period increase this feeding system becomes more economically valuable. The sensitivity analysis in this experiment shows that potential savings per cow can be as high as $33.09 per feeding period. This feeding system has the potential to be an effective and economically viable alternative feeding system for cow-calf producers in the Great Plains.

Table 3.1. The effect bale feeder type, monensin supplementation, and limit feeding on cow performance

	Treatment[1]			
Item, kg;	Control	Limit	SEM	*P*-value
BW;				
Allotment	531	533	14.12	0.93
d0	548	546	14.22	0.87
d28	562	550	14.13	0.40
d56	561	549	14.25	0.41
d84	555	556	14.39	0.94
Off test[3]	537	539	13.89	0.86
BW change;				
d28-d56	-2.0	-1.7	3.48	0.95
d56-d84	-5.8	6.2	2.69	0.01
d0-d84	4.5	10.4	5.91	0.33
d0-d28	11.8	4.6	4.27	0.10
d0-off test	-10.9	-6.4	5.36	0.41

[1]Control = ad libitum access to prairie hay, steel ring feeder, 38% CP cottonseed meal based pellet with 0 mg/hd monensin; Limit = 7 hours access to prairie hay, modified cone feeder, 38% cottonseed meal based pellet with 200 mg/head of monensin.

[3] Off Test = 12 h shrunk weight with cattle having ad libitum access to water. Cows were comingled in a pasture for 7 days after conclusion of the trial before off test weight to account for differences in fill.

Table 3.2. The effect of bale feeder type, monensin supplementation, and limit feeding on cow BCS

	Treatment[1]			
Item;	Control	Limit	SEM	*P*-value
BCS;				
d0	4.38	4.45	0.19	0.71
d28	4.57	4.42	0.21	0.50
d56	4.76	4.40	0.18	0.04
d84	4.84	4.82	0.19	0.92
BCS change;				
d0-d28	0.19	-0.08	0.15	0.08
d28-d56	0.19	-0.03	0.15	0.14
d56-d84	0.09	0.36	0.11	0.02
d0-d84	0.47	0.29	0.17	0.28

[1]Control = ad libitum access to prairie hay, steel ring feeder, 38% CP cottonseed meal based pellet with 0 mg/hd monensin; Limit = 7 hours access to prairie hay, modified cone feeder, 38% cottonseed meal based pellet with 200 mg/head of monensin.

Table 3.3. The effect of bale feeder type, monensin supplementation, and limit feeding on hay waste

	Treatment[1]			
Item, kg[2];	Control	Limit	SEM	*P*-value
Hay fed	630	632	14.66	0.89
Orts	79	109	18.54	0.15
Contaminated waste	70	46	4.08	0.01
Dry waste	87	29	3.77	0.01
Total waste	157	75	3.69	0.01
Bale weight wasted, %	24.9	11.9	0.86	0.01

[1]Control = ad libitum access to prairie hay, steel ring feeder, 38% CP cottonseed meal based pellet with 0 mg/hd monensin; Limit = 7 hours access to prairie hay, modified cone feeder, 38% cottonseed meal based pellet with 200 mg/head of monensin.

[2]All weights are on a dry matter basis.

Table 3.4. Effect of bale feeder type, monensin supplementation and limit feeding on net disappearance

	Treatment[1]			
Item, kg[2];	Control	Limit	SEM[3]	*P*-value
Hay fed	12,760	11,125	1,971.85	0.14
Orts	622	1,085	321.69	0.22
Net disappearance[3];				
Per pen	12,138	10,041	620.95	0.03
Per cow	1,012	837	51.75	0.03
Per cow/d	12.04	9.96	0.62	0.03

[1]Control = ad libitum access to prairie hay, steel ring feeder, 38% CP cottonseed meal based pellet with 0 mg/hd monensin; Limit = 7 hours access to prairie hay, modified cone feeder, 38% cottonseed meal based pellet with 200 mg/head of monensin.

[2]All weights are on a dry matter basis.

[3]Net disappearance is calculated by subtracting orts (hay removed from feeders) from hay fed.

Table 3.5. Effect of bale feeder type, monensin supplementation and limit feeding on intake

Item;	Treatment[1]		SEM	*P*- value
	Control	Limit		
Intake[3] per day per collection period, kg[2];				
Per pen	103.49	87.57	4.32	0.01
Per cow	8.62	7.30	0.36	0.01

[1]Control = ad libitum access to prairie hay, steel ring feeder, 38% CP cottonseed meal based pellet with 0 mg/hd monensin; Limit = 7 hours access to prairie hay, modified cone feeder, 38% cottonseed meal based pellet with 200 mg/head of monensin.

[2]All weights are on a dry matter basis.

[3] Intake was calculated by subtracting orts and total hay waste from hay fed during each collection period.

Table 3.6. Effect of bale feeder type, monensin supplementation and limit feeding on apparent digestibility

	Treatment[1]			
Item;	Control	Limit	SEM	*P-value*
Apparent Digestibility, %;				
DM	66.08	60.62	3.20	0.12
NDF	64.82	59.04	4.18	0.20
ADF	60.85	52.61	3.78	0.06
OM	69.27	64.21	4.17	0.14

[1]Control = ad libitum access to prairie hay, steel ring feeder, 38% CP cottonseed meal based pellet with 0 mg/hd monensin; Limit = 7 hours access to prairie hay, modified cone feeder, 38% cottonseed meal based pellet with 200 mg/head of monensin.

Table 3.7. Economics of bale feeder type, limit feeding, and monensin supplementation		
	Treatment[1]	
Item;	Control	Limit
Overhead cost, $/feeder/day;		
Bale feeder[3]	$ 91.00	$ 115.00
Fence[4]	$ 0.00	$ 45.33
Daily cost, $/cow/day;		
Supplement	$ 0.20	$ 0.20
Hay	$ 1.33	$ 1.10
Additive	$ 0.00	$ 0.02
Total Cost, $/cow;		
Per feeding period[2]	$ 135.99	$ 124.19
Per day	$ 1.56	$ 1.43
Total Cost, $/cow, optimum density[5];		
Per feeding period	$ 139.06	$ 125.48
Per cow	$ 1.60	$ 1.44

[1]Control = ad libitum access to prairie hay, steel ring feeder, 38% CP cottonseed meal based pellet with 0 mg/hd monensin; Limit = 7 hours access to prairie hay, modified cone feeder, 38% cottonseed meal based pellet with 200 mg/head of monensin.

[2] 84 days

[3] Purchase price depreciated over 5 years.

[4] Purchase price depreciated over 3 years.

[5] Optimum density is the maximum effective density of cows per feeder to minimize cost.

Table 3.8. Effect of hay cost and length of feeding period on total cost per cow per feeding period

	Cost of Hay, $ / Ton			
Item;	$ 50	$ 100	$ 150	$ 200
60 d feeding length				
CONT[1]	59	99	139	179
LIMIT[2]	60	93	125	158
80 d feeding length				
CONT	77	130	183	236
LIMIT	75	119	163	207
100 d feeding length				
CONT	94	160	227	293
LIMIT	90	145	200	255
120 d feeding length				
CONT	111	191	271	350
LIMIT	106	172	238	303

[1]Control = ad libitum access to prairie hay, steel ring feeder, 38% CP cottonseed meal based pellet with 0 mg/hd monensin.

[2]Limit = 7 hours access to prairie hay, modified cone feeder, 38% cottonseed meal based pellet with 200 mg/head of monensin.

Literature Cited

Belyea, R. L., F. A. Martz, and S. Bell. 1985. Storage and feeding losses of large round bales. J. Dairy Sci. 68:3371-3375.

Bretschneider, G., J. C. Elizalde and F. A. Perez. 2008. The effect of feeding antibiotic growth promoters on the performance of beef cattle consuming forage based diets: a review. Livest. Sci. 114:135-149.

Buskirk, D. D., A. J. Zanella, T. M. Harrigan, J. L. Van Lente, L. M. Gnagey and M. J. Kaercher. 2003. Large round bale feeder design affects hay utilization and beef cow behavior. J. Anim. Sci. 81:109-115.

Clanton, D. C., M. E. England and J. C. Parrott III. 1981. Effect of Monensin on efficiency of production in beef cows. J. Anim. Sci. 53:873-880.

Comerford, J. W., D. R. Buckmaster, and E. H. Cash. 1994. Effects of three storage methods on nutrient losses from harvest, storage and feeding of large bales. J. Anim. Sci. 72(Suppl. 2):130(Abstr.).

Hughes, H. 2013. Lower net returns expected for cowherds in 2013. http://beefmagazine.com/blog/lower-net-returns-expected-cowherds-2013 Accessed July 24, 2013.

Lemenager, R. P., F. N. Owens, K. S. Lusby and R. Totusek. 1978. Monensin, forage intake and lactation of range beef cows. J. Anim. Sci. 47:247-254.

Miller, A. J., D. B. Faulkner, R. K. Knipe, D. R. Strohbehn, D.F. Parrett, and L.L. Berger. 2001. Critical control points for profitability in the cow-calf enterprise. Prof. Anim. Sci. 17:95-302.

Miller, A. J., D. B. Faulkner, T. C. Cunningham, and J. M. Dahlquist. 2007. Restricting time of access to large round bales of hay affects hay waste and cow performance. Prof. Anim. Sci. 23:366-372.

Sexten, A, J., The effects of hay processing and feeder design on hay utilization. . Marter's Thesis. Oklahoma State Univ., Stillwater.

Wagner, J. J., K. S. Lusby, J. W. Oltjen, J. Rakestraw, R. P. Contaminatedtemann, and L. E. Walters. 1988. Carcass composition in mature Hereford cows: estimation and effect on daily metabolizable energy requirement during winter. J. Anim. Sci. 66:603-612

CHAPTER IV

EFFECTS OF BALE FEEDER TYPE, MONENSIN SUPPLEMENTATION, LIMIT FEEDING, AND HAY AMMONIATION ON HAY WASTE, INTAKE, AND PERFORMANCE OF BEEF CATTLE

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ABSTRACT

This experiment was conducted to evaluate the effects of bale feeder type, monensin supplementation, limit feeding, and hay ammoniation on hay waste, net disappearance, and cow performance. Lactating Angus and Angus x Hereford cows (n =36; 528 ± 63) were allotted by BW to one of two treatments. Treatment 1) (CONT; control included ad libitum access to a ring feeder with low quality prairie hay and 1.13 kg/d of a cottonseed meal based pellet. Treatment 2 included 6h access to a modified cone feeder with ammoniated prairie hay and 0.79 kg/d of a wheat middlings and cottonseed meal based pellet. Cows were allotted to one of four previously grazed 1 ha paddocks equipped with a 12.2 x 7.6 m^2 concrete pad. There was no difference (P = 0.14) in cow BW change between d 0 and off test. However, calves from cows receiving the LIMIT treatment gained less weight (P = 0.01) than those receiving the CONT treatment. Total hay waste was significantly ($P = 0.01$) reduced by the LIMIT treatment. Total waste was 134 and 48 kg for CONT and LIMIT treatments, respectively. CONT treatment wasted 21.9% of bale weight, compared to 7.3% for the LIMIT treatment. Net disappearance was significantly ($P = 0.01$) reduced by the LIMIT treatment. There was no economic benefit for the LIMIT treatment for the feeding period observed.

Key Words: beef cattle, hay waste, feeder design, monensin, ammoniation

INTRODUCTION

Feeding hay to beef cattle in the Great Plains is a very common management practice. There have been several technologies or management strategies developed to increase efficiency of beef cattle consuming forage, or harvested forage such as hay. These include, but are not limited to, hay feeder design, limiting access to hay, monensin supplementation and hay ammoniation. Feed for cattle can account for over 60% of the costs of a cow-calf operation (Miller et al., 2001). For 101 northern plains beef herds hay cost averaged $152 per cow exposed (Hughes, 2013). As input costs continue to rise, the ability to reduce feed costs by increasing hay feeding efficiency has the potential to greatly affect cow-calf profitability in the Great Plains.

Bale feeder type greatly affects the efficiency of hay feeding. Buskirk et al. (2003) observed ranges in waste as a percent of hay disappearance from 3.5 to 14.6% due to bale feeder type. Sexten et al. (2011) reported low efficiency feeders can waste up to 21.5% of a bale of hay. In the same study, Sexten et al. (2011) found that hay waste can be reduced by 74% by just by using a high efficiency feeder compared to a conventional ring feeder. Limiting access to hay is an effective method to decrease hay waste. Hay waste increases linearly as time of access increases (Miller et al., 2007). Depending on the quality of hay fed, limit feeding gives producers the ability to maintain acceptable cow performance while reducing the amount of hay wasted and consumed.

Supplementing beef cattle diets with monensin (MON) can potentially reduce the amount of hay needed to maintain cow performance by increasing efficiency of energy and nitrogen metabolism in the rumen (Clanton et al., 1981). Supplementing beef cow diets with MON has the potential to increase average daily gain (ADG) and increase feed conversion without affecting dry matter intake (DMI) (Bretschneider et al., 2008). The increase in efficiency of utilization of forage by cattle consuming MON can result in maintaining desired performance while decrease intake. Lemenager et al. (1978) observed a decrease in DMI but no difference in cow performance as MON supplementation increased from 0 to 200 mg/hd daily. Similar results were reported by Clanton et al. (1981), with a 10% feed savings and no difference in cow performance when MON was fed at 200 or 300 mg/hd daily.

Ammoniation of low quality forages can provide a unique benefit to cow-calf producers. Hay ammoniation can increase performance of animals by increasing passage rate and crude protein (CP) content of the hay (Zorrilla-Rios et al., 1991a). Additionally studies have shown an increase in fiber digestibility (Gates et al., 1987; Wyatt et al., 1989) due to hay ammoniation. Zorrilla-Rios et al. (1991b) found that ammoniated straw produced weight gains that were similar to wheat straw plus 500 g/d of soybean meal. Additionally, Vagnoni et al. (1995) found that ammoniated bermudagrass increased ADG in yearling steers by 0.14 kg/d. Ammoniation of low quality hay gives producers the ability to take a cheaper feed source and improve the nutritive value of the feed. This allows producers to benefit from increased performance of the cattle consuming the hay.

When hay feeding technologies are properly utilized the efficiency of hay utilization can be increased. Improved hay feeders can drastically reduce hay waste. Supplementing MON has the ability to either maintain cow performance while decreasing DMI, or increase ADG while not affecting DMI. Limit feeding, when combined with MON supplementation, may be able to reduce hay waste while maintain acceptable cow performance. Hay ammoniation has shown to increase the nutritive value of low quality hay while as well as increasing performance. The combination of these factors in a winter feeding system has not been well documented. Therefore, the purpose of this study was to determine hay disappearance, hay waste, and animal performance of a winter feeding system integrating these four underutilized technologies compared to a more conventional winter feeding system.

MATERIALS AND METHODS

This experiment was conducted at the Range Cow Research Center, North Range Unit, located approximately 16 km west of Stillwater, OK. Experimental protocols were approved by Oklahoma State University Animal Care and Use Committee. Thirty six lactating Angus and Angus x Hereford cows (528 ± 63 kg; 4.58 ± 0.68) were allotted by 12 h shrunk BW and assigned to one of two treatments. Treatment 1 (CONT; control) included ad libitum access to a steel ring feeder containing round bales of prairie hay (5.5% CP, 50% TDN) and 1.13 kg/d of a 38% CP cottonseed meal based supplement. Treatment 2 (LIMIT; limited) included limited access to a modified cone feeder containing ammoniated prairie hay (13.7% CP, 58% TDN) and 0.79 kg/d of a 20% CP wheat middlings and cottonseed meal based supplement with 200mg/d per head inclusion of monensin (MON, Rumensin 90®; Elanco Animal Health; Greenfield, IN). Wire panels were placed around the concrete pads to allow access for 6 h daily; starting at 0800 h. Cows were assigned to one of four pens measuring approximately two acres each, two pens per treatment. Each pen was previously grazed to remove standing forage and included a 12.2 x 7.6 m^2 concrete pad. Supplementation and hay feeding began February 12, 2013 (d 0) and ended April 16, 2013 (d 64).

Hay ammoniation

Sixty nine bales of prairie hay were ammoniated in September 2012. Hay was stacked in a triangle shaped stack. The stack was covered with a 6 mm black plastic tarp with rock screening placed around the outside edge to create a seal. Inclusion of anhydrous ammonia was 2.5% of hay DM. A hose was connected to a portable anhydrous ammonia tank and placed under the uphill end of the stack. Anhydrous ammonia was slowly released into the sealed stack. Several strong wind storms were encountered in September 2012. The black tarp sustained severe damage after three weeks of ammoniation. A color and texture change was observed. Hay was core sampled and analyzed to confirm enough time had elapsed for adequate ammoniation.

Waste Collection

Two waste collection periods were completed during the experiment. Waste collection periods are defined as the time required for a pen to consume 85% of a bale of hay. Prior to collection, cement pads were cleared of hay and debris, and all hay remaining within the feeders was removed, weighed, and sampled. Upon initiation of the collection period a fresh round bale was weighed, core sampled, and placed in each feeder. Hay waste was considered any hay that was found outside of the feeder. Most fecal material was removed from the collection pad. Hay was separated into contaminated and dry subgroups. Each subgroup was sampled and weight was adjusted for DM content. Contaminated hay waste was considered any hay that had fecal material, urine, or any precipitation that affected the DM content of the waste. Dry hay waste was any hay that was not highly contaminated. Hay waste was measured at 1300 h daily for the time required for 85% of the hay within each feeder to be consumed. At that point all remaining hay within the feeder was removed, weighed, and sampled and a new bale was placed in each feeder. All hay waste and orts were discarded after sampling. After hay was collected, it was weighed on a portable scale and sampled for further analysis. To minimize contamination. Fecal samples were taken daily during the collection period at 0900 h and 1800 h. Eight fecal grab samples were taken per pen each day of collection. Four random fresh samples were taken by hand within each pen per collection.

Cattle Measurements

Cows were weighed and allotted based on allotment BW. The following day cows were weighed again (d 0) and placed on treatment. A BW and BCS (1 to 9 scale; Wagner et al., 1988) was recorded on all cows on d 0, d 32, and d 62. BW was taken on calves on d 0, d 32, and d 62.

Cows and calves were removed from treatments on d 62 (April 15, 2013) and were comingled on pasture until a final weight was taken on April 22, 2013 to adjust for differences in fill between cattle receiving either treatment. On weigh d, cattle on the CONT treatments were moved at daylight and comingled with cattle in LIMIT pens where there was not access to hay. This was done to minimize fill differences due to hay intake immediately prior to collecting weights. Cattle were comingled before being weighed and body scored to remove any bias in measurements. Immediately following weighing and body scoring, cattle were returned to their respective treatments. Cattle had full access to automatic frost proof water tanks as well as ad libitum access to mineral. Total hay fed and orts were summed between d 0 and d 62. Net disappearance is defined as orts subtracted from total hay fed.

Chemical Analysis

All fecal samples and hay samples were oven dried at 50°C and DM was calculated on all hay samples. Dried samples were ground using a Wiley Mill (Model 4, Thomas Scientific, Sweedesboro, NJ). Fecal samples were ground through a 1 mm screen, all hay samples were ground to pass through a 2 mm screen. Hay waste, orts, and fecal samples were composited within pen, per collection period. Bale cores were composited within pen. Neutral Detergent Fiber and Acid Detergent Fiber were determined using an Ankom Fiber Analyzer (ANKOM Technology, 2005). Nitrogen content of the samples was determined using a Leco NS-2000 Nitrogen Analyzer (Leco Corporation, St. Joseph, MI). Apparent digestibility of hay was measured using ADIA as a marker.

Economics

Economics of the trial were calculated by using current prices of materials and inputs at the initiation of the study. Supplement and hay prices were market prices for Oklahoma for the winter of 2012-2013. Hay feeder prices were calculated using a five year depreciation schedule assuming no salvage value. Fence material prices were calculated using a three year depreciation schedule with no salvage value. Anhydrous ammonia cost used was from the observed price during the ammoniation process in September, 2012. Differences in calf price are reported. Sensitivity was performed using differences in prices of hay and length of feeding period. Economic benefit is reported as total savings per head per day

Statistical Analysis

Data were analyzed using the MIXED procedure of SAS (SAS Inst., Inc., Cary, NC). Pen was considered the experimental unit and the model included treatment as a fixed effect and collection period as a random effect. For all analyses, when the *P*-Value for the F-Statistic was $\leq$ 0.05, least square means were separated and reported. Tendencies were reported at 0.05 < P-Value $\leq$ 0.10.

RESULTS AND DISCUSSION

Cow Performance

This experiment was designed to use multiple technologies to improve hay feeding efficiency. The goal was to decrease hay disappearance while maintaining cow and calf performance. There was no difference between treatments for allotment BW (*P* = 0.98; Table 4.1), allotment BCS (*P* = 0.16; Table 4.2), or d 0 BW (*P* = 0.76). Additionally there was no difference in cow BW on d 32 (*P* = 0.21), d 62 (*P* = 0.29), or off test (*P* = 0.88). There was no difference for d 0-62 BCS change between treatments (*P* = 0.17). Cows receiving the LIMIT treatment only had access to hay 6 h/d. As expected, there were differences in cow BW change between treatments with cows receiving the CONT treatment losing less BW than cows receiving the LIMIT treatment between d 0-32 (*P* = 0.01) and d 0-62 (*P* = 0.01) as differences in fill were established. There was no difference between treatments for cow BW change d 0-off test. Cows receiving both treatments lost BW, -32 and -39 for CONT and LIMIT treatments, respectively.

Diets were designed to meet protein requirements, but weight loss in lactating beef cows consuming ad libitum low quality hay was expected due to not meeting NRC (2000) requirements for energy. Cows consuming the LIMIT treatment exhibited much less gut fill, often to the point of appearing in a decreasing body score, however body score was not significantly affected. Cows and calves also appeared to eat to their fill before the 6 h feeding period was over. The results from this study are supported by Miller et al. (2007) who found that cattle with limited access to hay were able to maintain acceptable levels of weight gain and BCS. Monensin supplementation has resulted in feed savings of 10% with no reduction in performance when cattle were fed medium to high quality hay (Clanton et al., 1981). In contrast, Bretschneider et al. (2008) found that monensin inclusion did not affect DMI. Limiting access to cattle on the LIMIT treatment was designed to reduce their DMI. It was predicted, however, that the combination of inclusion of MON and ammoniated hay would increase efficiency of hay being consumed, resulting in no difference in cow BW change. The cow performance of this study suggests that increased efficiency of hay consumed due to MON supplementation and limit feeding may have allowed cows receiving the LIMIT treatment to maintain performance on less hay than cows receiving the CONT treatment.

Calf Performance

Calf BW was not different between treatments on d 0 ($P = 0.96$; Table 4.3), d 32 ($P = 0.18$), d 62 ($P = 0.24$), or off test ($P = 0.47$). Calves receiving the LIMIT treatment gained less BW between d 0-62 ($P = 0.01$) and d 0-off test ($P = 0.01$). Calves receiving both treatments gained weight during the experiment; however, calves receiving the LIMIT treatment gained 7 kg less than calves receiving the CONT treatment. Differences in calf BW change during this study may be a result in differences in milk production. In a study conducted by Hargreaves et al. (1984) dairy cattle showed a significant ($P < 0.05$) decrease in milk production when consuming ammoniated stalklage, possibly due to the reduced intake in the ammoniated treatment. Data from

Brown et al. (2005) suggests that the genetic potential for milk yield and subsequent calf BW may have a practical maximum and may be limited by environment and nutrition. Calves consuming hay from the modified cone feeder may have had access to a lower quality diet than other calves. Due to the way cows pull hay from the bale above them, much of the hay that falls to the sheeted bottom is lower quality. At times, calves may not have had full access to hay that was suspended in the cone, leaving them only hay that has been sorted and left in the sheeted bottom. Cows consuming smaller amounts of ammoniated hay may have expressed a decrease in milk production due to consuming less forage than cows on the CONT treatment. Milk production was not measured but cow BW was not significantly decreased.

The literature on the effect of cow supplementation of ionophores and subsequent calf growth shows varied results. Clanton et al. (1981) found no difference in calf growth when dams were fed ionophores. Lemenager et al. (1978) found that calf BW gain was increased when their dams were fed 200 mg/hd monensin. They proposed that the increase in calf gain may be attributed to increased efficiency of milk and forage use due to calf consumption of the supplement being offered to the cow. In a trial conducted by Sprott et al. (1981) calves were not allowed access to the ionophore offered to the dams. Calves from cows receiving an ionophore had larger 120 d weights, but were not larger at weaning (Sprott et al., 1981). A decrease in calf BW change due to monensin, reduced intake, ammoniate hay, or an antagonistic combination of these factors could have resulted in the difference observed.

Hay Waste

Hay waste was significantly affected by treatment. The LIMIT treatment resulted in less contaminated waste, dry waste and total waste ($P \leq 0.01$; Table 4.4). There was a tendency (P = 0.10) for bale weight to be different between treatments for hay fed during collection periods. Bales of ammoniated hay were 54 kg heavier than non-ammoniated hay. Bale cores were oven dried to calculate DM to remove differences in hay moisture due to differences in hay storage. Differences in orts between treatments were significant (*P* <0.01) as was expected. Differences in orts were due to differences in timing of hay feeding and orts removal due to treatment, instead of due to cattle behavior due to treatment. Total waste was decreased (*P* < 0.01) in the LIMIT treatment by 86 kg per bale fed. Total waste in the CONT treatment was 134 kg, compared to only 48 kg of waste in the LIMIT treatment. This data is similar to findings from Miller et al. (2007), who found a linear increase in hay waste as time of access increased. Total waste expressed as a percent of bale weight was significantly decreased (*P* < 0.01) by the LIMIT treatment. Cattle receiving the CONT treatment wasted 21.9% of bale weight while cattle receiving the LIMIT treatment wasted only 7.3% of bale weight. Cattle receiving the CONT treatment wasted 14.6% percentage units more total waste as a percent of bale weight than the cattle receiving the LIMIT treatment. There is an astounding visual difference in the amount of hay waste, as expressed in figure 2. Very little hay was observed around the modified cone feeder, while large piles of hay are found around the ring feeder. The waste numbers in this data are higher than those reported in similar studies (Buskirk et al., 2003; Sexten et al., 2011), however, there have been large ranges of hay waste reported. The range across studies in bale feeder types have resulted in reported hay waste between 1.9% (Comerford et al., 1994) to 30% (Belyea et al., 1995). The amount of hay waste in the CONT treatment of this experiment was very similar to that observed in experiment one with 21.9 and 24.9% of bale weight wasted respectively. The hay in both studies was very low quality that resulted in less dense bales that could be responsible for more total waste. The hay waste as a percent of bale weight in experiment 1 was 11.9% for the LIMIT treatment, compared to 7.3% in this experiment. That is a larger reduction than the reduction in hay waste in the CONT treatment, suggesting that feeders containing ammoniated hay waste less than feeders containing non ammoniated hay. In this trial, hay waste was reduced by the LIMIT treatment by 67%, compared to 52% in experiment 1. A large portion of this reduction in hay waste may be attributed to ammoniation, due to the rather small change in time of access. The results of these data suggest that the differences in hay waste of this trial can be attributed to restricted access, feeder design, and hay ammoniation.

Net Disappearance and Intake

There was a large decrease ($P < 0.01$; Table 4.5) in hay fed between treatments. The cattle receiving the LIMIT treatment were fed 2,395 kg less per pen than cows receiving the CONT treatment. Orts were different ($P < 0.02$) among treatments, as expected. This difference is a result of differences in timing of orts and waste collection due to treatment differences, not a reflection of cow behavior or performance. Net disappearance was measured as hay fed minus orts. Net disappearance between treatments was highly significant ($P < 0.01$). The LIMIT treatment resulted in a decrease in net disappearance per day of 6 kg per cow. This resulted in a total hay savings of 2,986 kg per pen over the 62 d experiment. The reduction in net disappearance is likely due to the additive effects of all technologies combined in the LIMIT treatment. Intake was calculated by subtracting orts and hay waste from total hay fed during each collection period. Intake was reported on a per pen/d and a per cow/d basis. Differences in intake were not significant between cows on the CONT and LIMIT treatment (Table 4.6). However, The LIMIT treatment numerically reduced cow and calf intake on a per pen/d basis and a per pair/d basis, resulting in an 8.3 and 1.0 reduction in intake per pen/d and per pair/d, respectively. The results of DMI savings of Clanton et al. (1981), protein savings of Zorrilla-Rios et al. (1991b), and hay waste savings by (Buskirk et al., 2003; Sexten et al., 2011) support the decrease in net disappearance of the LIMIT treatment. Net disappearance is an effective indicator of hay feeding efficiency because it is a function of both hay waste and cow intake. The decrease in net disappearance in the LIMIT treatment suggests that the combination of technologies is an effective method to increase hay feeding efficiency.

Apparent Digestibility

The effects of bale feeder type, MON supplementation, and limit feeding, and hay ammoniation on apparent digestibility are shown in table 4.6. There was no difference ($P > 0.35$) in DM, NDF, ADF and OM total tract apparent digestibility between treatments. There was, however, a numerical decrease observed in DM, NDF, ADF, and OM total tract digestibility in cows receiving the LIMIT treatment. In a similar study Sexten et al. (2011) observed an increase ($P < 0.05$) in apparent digestibility in cows receiving MON supplementation, while there was no difference due to feeder type.

Economics

Costs associated with each treatment are different due to differences in overhead cost and daily costs. Overhead costs for this study are referred to as bale feeder and fence costs. These costs are depreciated for five years for the bale feeder and three years for the fencing materials. The modified cone feeder in the LIMIT treatment costs $575 dollars, compared to $455 for the ring feeder. The cost for the feeders is shown in table 4.7. The largest difference in cost between treatments is the cost of the fence. To limit access in the paddocks for this experiment a fence requiring five t-posts and 6 cattle panels was used. This resulted in an additional $45.33 of overhead for the LIMIT treatment. Additionally, calf weight gain was decreased, resulting in a loss of $21.73/hd due to lost revenue in calf sales at weaning. Due to the increased CP% of the ammoniated hay in the LIMIT treatment the supplement fed was designed to contain less CP. Cattle on the LIMIT treatment were fed 0.79 kg/d of a 20% CP supplement, compared to a 38% CP supplement being fed at 1.13 kg/d to the CONT group. The cost of the supplements were 403 and 311 $/ton for the CONT and LIMIT treatments respectively. This resulted in daily supplement costs of $0.50 and $0.27 for the CONT and LIMIT treatments, respectively. Hay cost per day was also reduced by the LIMIT treatment. The daily costs are presented on a per cow/d basis (Table 4.7). Total cost was found by dividing overhead costs by the number of cows per feeder, and multiplying number of days by the daily cost. The LIMIT treatment resulted in a decrease in net disappearance, which resulted in a decreased hay cost of $0.26/d. Overall, the cost/d of the CONT and LIMIT treatment was $2.86 and $2.88, respectively, per cow. Total cost for the CONT treatment (62 d, 8 cow-calf pairs/pen) was $177.11. The LIMIT treatment reduced the cost for the same period to $178.35. The economic sensitivity to hay price and length of feeding period can be seen in table 4.8. It was estimated that up to 12 cow/calf pairs would be able to properly utilize the feeders in the experiment. Overhead cost of the feeder and fence is a major factor in the economics of the feeding system. Spreading overhead cost over the maximum effective number of animals reduces total cost, therefore 12 cow-calf pairs is referred to as optimum density. The economics of each feeding systems at optimum density is shown in table 4.8. Cheap hay prices combined with a short feeding period result in no benefit of the combination of technologies in the LIMIT treatment. The LIMIT treatment does show substantial economic benefit as hay price increases up to $200/ton and length of feeding approaches 120 d, resulting in upwards of $127 saving for the feeding period.

General Discussion

This experiment used stacked hay feeding efficiency technologies in a systems approach to determine the possible reduction in hay waste while maintaining cow performance. During the feeding period cow BW change was not different between treatments. Cattle receiving the LIMIT treatment were given less access to hay, but were able to utilize the hay available to them at a high enough level of efficiency to maintain performance with cattle having ad libitum access. The LIMIT treatment also resulted in significantly less total hay waste, less net disappearance, and numerically less hay intake. The experimental design of the experiment does not allow results to be attributed to any single factor used. In a study conducted using the same bale feeder, pens and cow herd, Sexten et al. (2011) observed an increase in cow BW gain when MON was fed and a decrease in hay waste when high efficiency bale feeders were used. Because of this weight gain response, we hypothesized that reducing access to hay would not only reduce hay waste, but would reduce intake slightly without sacrificing cow performance. The ability to decrease the amount of hay fed to beef cattle could potentially have positive economic benefits to cow-calf producers. This experiment resulted in a loss of $1.25 per cow over a 62 d feeding period. The economics of this system are somewhat dependent on spreading the overhead costs of fencing materials and bale feeder over a larger feeding period. Supplement and hay cost per day is decreased in the LIMIT treatment. Due to this daily savings, as hay prices and days in the feeding period increase this feeding system becomes more economically valuable. Potential savings per cow in the sensitivity in this experiment can be as high as $65.84 per feeding period. This feeding system has the potential to be an effective and economically viable alternative feeding system for cow-calf producers in the Great Plains.

Table 4.1. Effect of bale feeder type, monensin supplementation, limit feeding, and hay ammoniation on cow performance

	Treatment[1]			
Item, kg;	Control	Limit	SEM	*P*-value
BW;				
Allotment	528	528	22.77	0.98
d0	524	527	22.85	0.89
d32	529	499	23.73	0.21
d62	521	496	23.17	0.29
Off Test	491	488	21.92	0.88
BW change;				
d32-d62	-8.0	-2.7	3.73	0.16
d0-d32	-5.7	-28.2	3.54	0.01
d0-d62	-2.4	-30.8	4.62	0.01
d0-off test[2]	-32.5	-39.1	4.40	0.14

[1]Control = Ad libitum access to prairie hay, steel ring feeder, 38% CP cottonseed meal based pellet with 0 mg/hd monensin; Limit = 6 hours access to prairie hay, modified cone feeder, 20% cottonseed meal based pellet with 200 mg/head of monensin.

[2] Off Test = Cows were comingled in a pasture for 7 days after conclusion of the trial before off test weight to account for differences in fill.

Table 4.2. Effect of bale feeder type, monensin supplementation, limit feeding, and hay ammoniation on cow BCS.

	Treatment[1]			
Item;	Control	Limit	SEM	*P*-value
BCS;				
Allotment	4.41	4.76	0.24	0.16
d32	4.57	4.52	0.30	0.86
d62	4.27	4.34	0.36	0.84
BCS change;				
d32-d62	-0.3	-0.17	0.18	0.49
d0-d32	0.17	-0.24	0.17	0.02
d0-d62	-0.13	-0.41	0.20	0.17

[1]Control = Ad libitum access to prairie hay, steel ring feeder, 38% CP cottonseed meal based pellet with 0 mg/hd monensin; Limit = 6 hours access to prairie hay, modified cone feeder, 20% cottonseed meal based pellet with 200 mg/head of monensin.

Table 4.3. Effect of bale feeder type, monensin supplementation, limit feeding, and hay ammoniation on calf performance

	Treatment[2]			
Item, kg;	Control	Limit	SEM	*P*-value
BW;				
d0	163	164	7.22	0.96
d32	193	182	7.59	0.18
d62	212	202	8.08	0.24
Off Test	210	204	8.42	0.47
BW change;				
d32-d62	19	20	1.68	0.63
d0-d32	29	19	1.65	0.01
d0-d62	48	38	1.95	0.01
d0-off test[2]	47	40	2.29	0.01

[1]Control = Ad libitum access to prairie hay, steel ring feeder, 38% CP cottonseed meal based pellet with 0 mg/hd monensin; Limit = 6 hours access to prairie hay, modified cone feeder, 20% cottonseed meal based pellet with 200 mg/head of monensin.

[2] Off Test = Cows were comingled in a pasture for 7 days after conclusion of the trial before off test weight to account for differences in fill.

Table 4.4. Effect of bale feeder type, monensin supplementation, limit feeding, and hay ammoniation on hay waste

	Treatment[1]			
Item, kg[2];	Control	Limit	SEM	*P*-value
Hay fed	638	692	26.67	0.10
Orts	105	180	16.82	0.01
Contaminated waste	50	11	7.47	0.01
Dry waste	72	26	7.32	0.01
Total waste	134	48	6.72	0.01
Bale weight Wasted, %	21.86	7.25	1.85	0.01

[1]Control = Ad libitum access to prairie hay, steel ring feeder, 38% CP cottonseed meal based pellet with 0 mg/hd monensin; Limit = 6 hours access to prairie hay, modified cone feeder, 20% cottonseed meal based pellet with 200 mg/head of monensin.

[2]All weights are on a dry matter basis.

Table 4.5. Effect of bale feeder type, monensin supplementation, limit feeding, and hay ammoniation on net disappearance

Item, kg[2];	Treatment[1] Control	Limit	SEM	*P*-value
Hay fed	10,325	7,931	58.88	0.01
Orts	562	1,154	95.08	0.02
Net disappearance;				
Per pen	9,763	6,777	70.00	0.01
Per cow	1,220	847	8.34	0.01
Per cow/day	19.68	13.66	0.14	0.01

[1]Control = Ad libitum access to prairie hay, steel ring feeder, 38% CP cottonseed meal based pellet with 0 mg/hd monensin; Limit = 6 hours access to prairie hay, modified cone feeder, 20% cottonseed meal based pellet with 200 mg/head of monensin.

[2]All weights are on a dry matter basis.

Table 4.6. Effect of bale feeder type, monensin supplementation and limit feeding on intake				
	Treatment[1]			
Item;	Control	Limit	SEM	*P*- value
Intake[3] per day per collection period, kg[2];				
Per pen	106.72	98.43	5.90	0.21
Per pair	13.34	12.30	0.74	0.22

[1]Control = Ad libitum access to prairie hay, steel ring feeder, 38% CP cottonseed meal based pellet with 0 mg/hd monensin; Limit = 6 hours access to prairie hay, modified cone feeder, 20% cottonseed meal based pellet with 200 mg/head of monensin.

[2]All weights are on a dry matter basis.

[3] Intake was calculated by subtracting orts and total hay waste from hay fed during each collection period.

Table 4.7. Effect of bale feeder type, monensin supplementation, limit feeding, and hay ammoniation on apparent digestibility				
	Treatment[1]			
Item;	Control	Limit	SEM	P-value
Apparent Digestibility, %;				
DM	75.41	66.21	8.94	0.35
NDF	77.17	70.95	7.60	0.45
ADF	70.51	60.45	9.94	0.36
OM	77.10	68.38	8.42	0.35

[1]Control = Ad libitum access to prairie hay, steel ring feeder, 38% CP cottonseed meal based pellet with 0 mg/hd monensin; Limit = 6 hours access to prairie hay, modified cone feeder, 20% cottonseed meal based pellet with 200 mg/head of monensin.

Table 4.8. Economics of bale feeder type, monensin supplementation, limit feeding, and hay ammoniation

	Treatment[1]	
Item,	Control	Limit
Overhead cost, $/feeder/year;		
Bale feeder[2]	$ 91.00	$ 115.00
Ence[3]	$ 0.00	$ 45.33
Daily cost, $/cow/d;		
Supplement	$ 0.50	$ 0.27
Hay	$ 2.17	$ 1.91
Additive	$ 0.00	$ 0.02
Total Cost, $/cow;		
Per feeding period[4]	$ 177.11	$ 178.36
Per day	$ 2.86	$ 2.88
Total Cost, $/cow, optimum density[5];		
Per feeding period	$ 173.31	$ 171.67
Per day	$ 2.80	$ 2.77

[1]Control = Ad libitum access to prairie hay, steel ring feeder, 38% CP cottonseed meal based pellet with 0 mg/hd monensin; Limit = 6 hours access to prairie hay, modified cone feeder, 20% cottonseed meal based pellet with 200 mg/head of monensin.

[2] Purchase price depreciated over 5 years.

[3] Purchase price depreciated over 3 years.

[4] 62 days

[5] Optimum density is the maximum effective density of cows per feeder to minimize cost.

Table 4.9. Effect of hay cost and length of feeding period on total cost per cow per feeding period

Item;	Cost of Hay, $ / Ton			
	$ 50	$ 100	$ 150	$ 200
60 d feeding length				
Cont[1]	107	172	237	302
Limit[2]	129	174	219	264
80 d feeding length				
Cont	138	225	312	399
Limit	158	218	278	338
100 d feeding length				
Cont	170	279	387	496
Limit	187	262	337	391
120 d feeding length				
Cont	202	332	462	592
Limit	215	306	396	465

[1]Control = Ad libitum access to prairie hay, steel ring feeder, 38% CP cottonseed meal based pellet with 0 mg/hd monensin.

[2]Limit = 6 hours access to prairie hay, modified cone feeder, 20% cottonseed meal based pellet with 200 mg/head of monensin.

Literature Cited

Belyea, R. L., F. A. Martz, and S. Bell. 1985. Storage and feeding losses of large round bales. J. Dairy Sci. 68:3371-3375.

Bretschneider, G., J. C. Elizalde and F. A. Perez. 2008. The effect of feeding antibiotic growth promoters on the performance of beef cattle consuming forage based diets: a review. Livest. Sci. 114:135-149.

Brown. M. A., S. W. Coleman, and D. L. Lalman. 2005. Relationship of sire expected progeny differences to milk yield in brangus cows. J. Anim. Sci. 83:1194-1201.

Buskirk, D. D., A. J. Zanella, T. M. Harrigan, J. L. Van Lente, L. M. Gnagey and M. J. Kaercher. 2003. Large round bale feeder design affects hay utilization and beef cow behavior. J. Anim. Sci. 81:109-115.

Clanton, D. C., M. E. England and J. C. Parrott III. 1981. Effect of Monensin on efficiency of production in beef cows. J. Anim. Sci. 53:873-880.

Comerford, J. W., D. R. Buckmaster, and E. H. Cash. 1994. Effects of three storage methods on nutrient losses from harvest, storage and feeding of large bales. J. Anim. Sci. 72(Suppl. 2):130(Abstr.).

Gates, R. N., T. J. Klopfenstein, S. S. Waller, W. W. Stroup, R. A. Britton and B. F. Anderson. 1987. Influence of thermo-ammoniation on quality of warm-season grass hay for steers. J. Anim. Sci. 64:1821-1834.

Hargreaves, A., J. T. Huber, J. Arroyoluna, and L. Kung, Jr. 1984. Influence of adding ammonia to corn stalklage on feeding value for dairy cows and on fermentation changes. J. Anim. Sci. 59:567-575.

Hughes, H. 2013. Lower net returns expected for cowherds in 2013. http://beefmagazine.com/blog/lower-net-returns-expected-cowherds-2013 Accessed July 24, 2013.

Lemenager, R. P., F. N. Owens, K. S. Lusby and R. Totusek. 1978. Monensin, forage intake and lactation of range beef cows. J. Anim. Sci. 47:247-254.

Miller, A. J., D. B. Faulkner, R. K. Knipe, D. R. Strohbehn, D.F. Parrett, and L.L. Berger. 2001. Critical control points for profitability in the cow-calf enterprise. Prof. Anim. Sci. 17:95-302.

Miller, A. J., D. B. Faulkner, T. C. Cunningham, and J. M. Dahlquist. 2007. Restricting time of access to large round bales of hay affects hay waste and cow performance. Prof. Anim. Sci. 23:366-372.

NRC. 2000. Nutrient requirements of beef cattle. Seventh revised edition. Natl. Acad. Press, Washington, DC.

Sexten, A, J., The effects of hay processing and feeder design on hay utilization. . Marter's Thesis. Oklahoma State Univ., Stillwater.

Sprott L. R., T. B. Goehring, J. R. Beverly and L. R. Corah. 1988. Effects of Ionophores on cow herd production: a review. J. Anim. Sci. 66:1340-1346.

Vagnoni, D. B., W. M. Craig, R. N. Gates, W. E. Wyatt and L. L. Southern. 1995. Monensin and ammoniation or urea supplementation of bermudagrass hay diets for steers. J. Anim. Sci. 73:1793-1802.

Wagner, J. J., K. S. Lusby, J. W. Oltjen, J. Rakestraw, R. P. Contaminatedtemann, and L. E. Walters. 1988. Carcass composition in mature Hereford cows: estimation and effect on daily metabolizable energy requirement during winter. J. Anim. Sci. 66:603-612

Wyatt, W. E., W. M. Craig, R. N. Gates, F. G. Hembry and D. L. Thompson, Jr. 1989. Effects of ammoniated berumdagrass hay and monensin supplementation on heifer postweaning growth. J. Anim. Sci. 68:1698-1706.

Zorrilla-Rios, J., G. W. Horn, R. W. McNew. 1991a. Nutritive value of ammoniated wheat straw fed to cattle. J. Anim. Sci. 69:283-294.

Zorrilla-Rios, J., G. W. Horn, W. A. Phillips, and R.W. McNew. 1991b. Energy and protein supplementation of ammoniated wheat straw diets for growing steers. J. Anim. Sci. 69:1809-1819.

REFERENCES

Baxter, H. D., B. L. Bledsoe, M. J. Montgomery, and J. R. Owen. 1986. Comparison of alfalfa-orchardgrass hay stored in large round bales and conventional rectangular bales for lactating cows. J. Dairy Sci. 69:1854-1864.

Belyea, R. L., F. A. Martz, and S. Bell. 1985. Storage and feeding losses of large round bales. J. Dairy Sci. 68:3371-3375.

Bretschneider, G., J. C. Elizalde and F. A. Perez. 2008. The effect of feeding antibiotic growth promoters on the performance of beef cattle consuming forage based diets: a review. Livest. Sci. 114:135-149.

Brown. M. A., S. W. Coleman, and D. L. Lalman. 2005. Relationship of sire expected progeny differences to milk yield in brangus cows. J. Anim. Sci. 83:1194-1201.

Buettner, M. R., Lechtenberg, K. S. Hendrix and J. M Hertel. 1982. Composition and digestion of ammoniated tall fescue (*Festuca arundinacea schreb*.) hay. J. Anim. Sci. 54:173-178.

Burrell W. C. 1977. The effect of monensin in lactating beef cows in poor body condition receiving low levels of energy. PhD. Dissertation. Texas A&M Univ., College Station.

Buskirk, D. D., A. J. Zanella, T. M. Harrigan, J. L. Van Lente, L. M. Gnagey and M. J. Kaercher. 2003. Large round bale feeder design affects hay utilization and beef cow behavior. J. Anim. Sci. 81:109-115.

Chalupa, W. 1979. Chemical control of rumen microbial metabolism. In: Digestive Physiology and Metabolism in Ruminants. In: Ruckebusch, Y., Thivend, P. (Eds.), Proc. Fifth International Symposium on Ruminant Physiology. Cleremont-Ferrand, pp. 325-347.

Clanton, D. C., M. E. England and J. C. Parrott III. 1981. Effect of Monensin on efficiency of production in beef cows. J. Anim. Sci. 53:873-880.

Comerford, J. W., D. R. Buckmaster, and E. H. Cash. 1994. Effects of three storage methods on nutrient losses from harvest, storage and feeding of large bales. J. Anim. Sci. 72(Suppl. 2):130(Abstr.).

Ellis, W. C., Horn, G. W., Delaney, D., Pond, K. R., 1984. Effects of ionophores on grazed forage utilization and their economic value for cattle on wheat pasture. In: Horn, G. W. (Ed.), Proc. Nat. Wheat Pasture Sypm. Oklahoma State University, pp. 343-355. MP-115.

Gates, R. N., T. J. Klopfenstein, S. S. Waller, W. W. Stroup, R. A. Britton and B. F. Anderson. 1987. Influence of thermo-ammoniation on quality of warm-season grass hay for steers. J. Anim. Sci. 64:1821-1834.

Grotheer, M. D., D. L. Cross, L. W. Grimes, W. J. Caldwell and L. J. Johnson. 1985. Effect of moisture level and injection of ammonia on nutrient quality and preservation of coastal berumdagrass hay. J. Anim. Sci. 61:1370.

Hanson, T. L., and T. Klopfenstein. 1979. Monensin, protein source and protein levels for growing steers. J. Anim. Sci. 48:474.

Hargreaves, A., J. T. Huber, J. Arroyoluna, and L. Kung, Jr. 1984. Influence of adding ammonia to corn stalklage on feeding value for dairy cows and on fermentation changes. J. Anim. Sci. 59:567-575.

Hughes, H. 2013. Lower net returns expected for cowherds in 2013. http://beefmagazine.com/blog/lower-net-returns-expected-cowherds-2013 Accessed July 24, 2013.

Lemenager, R. P., F. N. Owens, K. S. Lusby and R. Totusek. 1978. Monensin, forage intake and lactation of range beef cows. J. Anim. Sci. 47:247-254.

Landbolm, D. G., G. P. Lardy, R. Fast, C. J. Wachenheim, and T. S. Petry. 2007. Effect of hay feeding methods on cow performance, hay waste, and wintering cost. Prof. Anim. Sci. 23:246-252.

Loerch, S. C. 1996. Limit feeding corn as an alternative to hay for gestating beef cows. J. Anim. Sci. 74:1211

Lemenager, R. P., F. N. Owens, K. S. Lusby and R. Totusek. 1978. Monensin, forage intake and lactation of range beef cows. J. Anim. Sci. 47:247-254.

Mertens, D. R. 1992. Nonstructural and structural carbohydrates. In: H. H. Van Horn and C. J. Wilcox (Ed.) Large Dairy Herd Management. Pp 219-235. Am Dairy Sci. Assoc., Champaign, IL.

Miller, A. J., D. B. Faulkner, R. K. Knipe, D. R. Strohbehn, D.F. Parrett, and L.L. Berger. 2001. Critical control points for profitability in the cow-calf enterprise. Prof. Anim. Sci. 17:95-302.

Miller, A. J., D. B. Faulkner, T. C. Cunningham, and J. M. Dahlquist. 2007. Restricting time of access to large round bales of hay affects hay waste and cow performance. Prof. Anim. Sci. 23:366-372.

Moore, K. J., V. L. Lechtenberg, K. S. Hendrix, and J. M. Hertel. 1981. Improving hay quality by ammoniation. In: Proc. 14th Int. Grassl. Conf. Lexington, KY. Pp 626-628. Westview Press, Boulder, CO.

NRC. 2000. Nutrient requirements of beef cattle. Seventh revised edition. Natl. Acad. Press, Washington, DC.

Saenger, P. F., R. P. Lemenager and K. S. Hendrix. 1982. Anhydrous ammonia treatment of corn stover and its effects on digestibility intake and performance of beef cattle. J. Anim. Sci. 54:419.

Saenger, P. F., R. P. Lemenager and K. S. Hendrix. 1983. Effects of anhydrous ammonia treatment of wheat straw upon in vitro digestion, performance and intake by beef cattle. J. Anim. Sci. 56:15-20.

Sankaram, M.E., Shastri, B.P., Easwaran, K.R.K. 1985. Mechanisms of transmembrane cation transport studied by nuclear magnetic resonance spectroscopy. Proc. Int. Symp. Biomol. Struct. Interactions, Suppl. J. Biosci. 8:343-354.

Sexten, A, J., The effects of hay processing and feeder design on hay utilization. . Marter's Thesis. Oklahoma State Univ., Stillwater.

Sprott L. R., T. B. Goehring, J. R. Beverly and L. R. Corah. 1988. Effects of Ionophores on cow herd production: a review. J. Anim. Sci. 66:1340-1346.

Vagnoni, D. B., W. M. Craig, R. N. Gates, W. E. Wyatt and L. L. Southern. 1995. Monensin and ammoniation or urea supplementation of bermudagrass hay diets for steers. J. Anim. Sci. 73:1793-1802.

Vestal, M., W. clement, D. Doye, D. Lalman. 2007. Cow-calf production practices in Oklahoma part 1. http://agecon.okstate.edu/faculty/publications/2814.pdf. Accessed April 10, 2013.

Wagner, J. J., K. S. Lusby, J. W. Oltjen, J. Rakestraw, R. P. Contaminatedtemann, and L. E. Walters. 1988. Carcass composition in mature Hereford cows: estimation and effect on daily metabolizable energy requirement during winter. J. Anim. Sci. 66:603-612

Walker, P. M., B. A. Weichenthal and G. F. Cmarik. 1980. Efficacy of monensin for beef cows. J. Anim. Sci. 51:532.

Wyatt, W. E., W. M. Craig, R. N. Gates, F. G. Hembry and D. L. Thompson, Jr. 1989. Effects of ammoniated berumdagrass hay and monensin supplementation on heifer postweaning growth. J. Anim. Sci. 68:1698-1706.

Zorrilla-Rios, J., G. W. Horn, R. W. McNew. 1991a. Nutritive value of ammoniated wheat straw fed to cattle. J. Anim. Sci. 69:283-294.

Zorrilla-Rios, J., G. W. Horn, W. A. Phillips, and R.W. McNew. 1991b. Energy and protein supplementation of ammoniated wheat straw diets for growing steers. J. Anim. Sci. 69:1809-1819.

Zorrilla-Rios, J., F. N. Owens, G. W. Horn and R. W. McNew. 1985. Effect of ammoniation of wheat straw on performance and digestion kinetics in cattle. J. Anim. Sci. 60:184.

APPENDICES

Figure 1.

Left: Steel ring feeder h 24
Right: Modified cone feeder h 24

Figure 2.

Left: Steel ring feeder h 24
Right: Modified cone feeder h 24

VITA

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