THE EFFECTS OF HAY PROCESSING AND FEEDER DESIGN ON HAY UTILIZATION

By

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INTRODUCTION

Harvested feed is the largest cost contributor to maintaining a profitable beef cattle herd (Miller et al., 2001). The most common form of packaging, storing and feeding hay in a beef operation is that of large round bales because of labor efficiency, and simplified hay handling (Belyea et al., 1985). There are many factors that affect overall dry matter loss of large round bales including storage and feeding methods, as well as the physical and chemical make up of the forage. Additionally, all of the previously listed factors can affect animal intake of the forage as well. There has been little research conducted as to the differences between hay feeding types and their respective effects on the combination of hay losses and hay intake. Also, the idea of processing the hay prior to baling is a new concept that could potentially have dramatic effects on both waste, as well as, animal intake. However, little research has been done regarding feeding methods and factors affecting forage intake in beef cattle. Until recently, most of the research in this area has been confined to the dairy industry. The objectives of this thesis are to determine the effects of hay processing and feeder design 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. 17:295-302

CHAPTER II

LITERATURE REVIEW

FACTORS THAT AFFECT HAY WASTE

Hay Storage Losses

One of the greatest causes of dry matter (DM) loss in hay production is the result of storage. There are several methods of storing large round bales of hay, the most common being the construction of rows of bales stacked end to end on the ground exposed to the elements. Storage losses can range from 2 to 18% of the dry matter, depending on the type of forage, storage method, environmental conditions, and length of time stored (Huhnke, 1987). Lechtenberg and others conducted a weathering study on several forms of stored hay, including large round bales and large compressed hay stacks. The objective of the study was to determine the amount and severity of weather deterioration with grass hay stored outside in large packages (Lechtenberg et al., 1974). The hay was stored outside from June through November, at which time, four of each of the treatments were weighed and physically separated into a weathered portion and an unweathered portion. This study found that the compressed hay stack yielded the least amount of waste due to weathering compared to the large round bales, with 12.6 and 22.3% loss respectively (Lechtenberg et al., 1974). This difference between the two storage methods was attributed to the difference in bale density. However this study shows the difference between the various forms of hay storage in relation to storage losses.

In an effort to decrease storage losses to round bales Brasche et al. (1988) conducted a study in which different storage methods were utilized. In this experiment large round bales of both bromegrass and Alfalfa–bromegrass were baled and stored in rows either on the ground uncovered or elevated on tires and covered by plastic sheets. They found that the primary advantage of the protective storage of large round bales was increased DM recovery, which was improved by an average of 4.5% in this experiment (Brasche et al., 1988).

Belyea et al. (1985) conducted yet another storage trail to try and determine losses due to storage method. In this trial, the storage methods for the large round bales included: 1) in a barn; 2) outside in single rows and uncovered; 3) outside in two high stacks and covered; and 4) outside in three high stacks and covered. The objective of this study was to show not only how storage method affected DM losses, but also how storage method affected subsequent feeding losses. With regard to the storage losses the bales that were stored inside the barn had the least amount of loss during storage at 2.5%, followed by bales stored outside and stacked two high and three high and covered at 5.8 and 6.6%, respectively, with bales stored outside and uncovered having the most storage loss at 15.0% (Belyea et al., 1985). The hay was then fed to heifers in an effort to determine the feeding losses caused by each method of storage. The hay was fed in feeders with angled slats in an attempt to keep the cattle from pulling out hay to consume and thus reduce hay waste. The feeding losses followed a similar pattern as the storage losses in that the hay that was stored inside the barn had the least amount of feeding loss with 12.4% respectively (Belyea et al., 1985). Again, the hay that was stored outside uncovered had the most feeding losses at 24.7% (Belyea et al., 1985). This large feeding loss can be attributed to the unpalatable material that had been penetrated by the weather and thus was sorted out and subsequently refused by the heifers. Belyea et al. (1985) concluded that the large storage and feeding losses of large round bales stored outside and uncovered were economically important enough to justify protection form the elements.

Another form of loss that can occur during storage is loss that is caused by hay that spontaneously heats and reduces nutritive value of the forage. Common terms of this phenomenon are Maillard Reaction, the nonenzymatic browning reaction and the browning reaction (Goering et al., 1973). Goering and others reported that the result of this reaction is a dark colored nitrogenous polymer that accumulates within the lignin fraction of acid detergent insoluble fiber (ADF). This is often caused by hay that is baled at a moisture concentration that is too high. These changes can result in a dramatic decrease in the nutritive value of the hay, resulting in decreased animal performance (Coblentz et al., 2000). Coblentz et al. conducted an experiment to examine the effects of initial bale moisture and bale density on spontaneous heating. Hay was baled at five different moisture concentration levels in an attempt to cause bales to spontaneously heat once stored. Additionally, bales were produced at both medium and high densities. It was reported by Coblentz et al. that bale density had little effect on forage nutritive value after storage as well as the incidence of spontaneous heating. It was found that concentrations of acid detergent insoluble nitrogen (ADIN) and neutral detergent insoluble nitrogen (NDIN) were positively related to measure of spontaneous heating (Coblentz et al., 2000).

Hay Feeding Method

How a producer presents hay to cattle to be consumed can play a major role in the amount of hay that is wasted. There are several different ways for hay to be fed. One of the most common of these is the use of a hay ring feeder. These feeders vary in shape and size, but all have the same common design in an effort to keep the cattle from trampling the hay, and rendering it unpalatable. In a study to determine hay DM loss when feeding large round bales of hay in a cone, ring, trailer, and cradle-type feeders Buskirk et al. tried to determine the most efficient way to feed hay to cows. In this study 160 non lactating cows were used to measure the amount of DM waste in bales fed in the aforementioned feeder types. Each pen had a different feeder type, to which the cows were given ad libitum access to. Hay that fell on the ground outside of the feeder was considered waste and was collected every 24 hours. At the end of a 7 day collection period all waste was collected as well as any residual hay within the feeders. The feeders were then reassigned to a different pen and fresh bales were placed and a new collection period began. This rotation continued until each pen had been exposed to each feeder type. Regarding the effect of feeder type on hay waste the cone feeder produced the least amount of waste amongst all the other feeder designs with 3.5% waste respectively

(Buskirk et al., 2003). The ring feeder had the next lowest amount of waste at 6.1%, followed by the trailer and cradle feeders at 11.4 and 14.6% respectively. Buskirk made the observation that the cattle eating from the cone and ring feeders more closely mimicked the grazing position than the cattle eating from the trailer and cradle designs, which could have been a contributing factor to the two feeders having the least amount of waste. Buskirk et al. also reported that hay waste as a percentage of hay disappearance, was less for the cone and ring feeders compared to the trailer and cradle feeders ($P < 0.05$).

Additionally, the trial conducted by Buskirk looked at the effect of the feeder type on cow behavior, and how cow behavior consequently affected hay waste. The most noticeable fact of the behavior data is that the animals feeding from a cradle feeder had nearly three times the agnostic interactions and four times the frequency of entrances compared to cows using the other feeders. Feed losses were positively correlated with agnostic interactions, frequency of regular and irregular entrances to the feeder, and feeder occupancy rate ($P < 0.05$) Buskirk reported. This goes to show the potential economic consequences regarding a producer's profitability that feeder selection has.

In another experiment, Landblom and others conducted an investigation into the effect of hay feeding method on cow wintering cost. In this trial cow were randomly assigned to one of four treatments, which were: 1) round bales fed by unrolling out on ground, 2) round bales shredded with a bale processor then fed on the ground, 3) round bales fed by being placed in a tapered-cone bale feeder. The study was conducted over a three year period in which it was repeated each winter. Two different types of hay were fed during various years of the study, alfalfa and oat hay. When alfalfa was fed the cone feeder was determined to be the least wasteful among feeding methods with 4.3 to 5.0 times less waste than either the roll out or bale processor method (Landbolm et al., 2007). However, when the looser packed oat hay bales were fed the waste was less than the waste of the bale processor but not significantly different. Landbolm also reported in an economic analysis that wintering costs per cow were $109, $127, and $100 for rolling bales out, using a bale processor, and feeding bales in a tapered cone feeder respectively in a 100 head cow herd. Furthermore, the effect of the three feeding methods on cow performance was also measured by calculating average daily gain (ADG). Cows that were fed using the tapered cone gained more than the other two treatments numerically, but the only significant difference was between the tapered cone cows and the cows fed by rolling the bales out on the ground ($P < 0.05$). With these results as well as the economic analysis in mind it is easy to see the benefits to purchasing a cone feeder over a bale processor.

Comerford et al. (1994) also found that feeder type was a source of significant feeding losses when feeding hay to beef cows. In this experiment two feeder types were used: conventional ring feeders and a raised cone-type feeder. The resulting hay waste determined for each feeder was 8.0% and 1.9% loss of DM offered for the conventional ring and raised cone respectively ($P < 0.02$) (Comerford et al., 1994).

Miller et al. (2007) conducted an experiment that restricted the amount of time cows had access to alfalfa hay to determine the effects of varying access times on hay waste and cow performance. In this trial cows were allotted to one of four treatments of hay access time: ad libitum (no restriction) or time restricted to 9, 6, or 3 h/d access (Miller et al., 2007). Cow BW and BCS change was different between treatments and increased as access time increased (P < 0.01) (Miller et al., 2007). With regard to the treatment's effects on hay waste, Miller et al. again found that hay waste was significantly different between treatments at 2.7, 2.6, 4.2, and 6.1 kg DM/d for 3, 6, 9 h and ad libitum access to hay respectively (P < 0.01) (2007).

Windrow grazing is another method of feeding hay was evaluated against feeding large round bales in ring feeders. Windrow or swath grazing is a method where livestock graze windrow stored forage directly out of the field as a replacement to feeding round bales of hay. The objective of the study conducted by Volesky et al. (2002) was to quantify calf performance and forage intake and waste under windrow grazing and bale fed management strategies.

FACTORS THAT AFFECT HAY INTAKE

Physical Form of Forage

There are several characteristics of forages commonly found in diets that can affect DMI in both positive and negative ways. The NRC lists several of these factors starting with a protein deficiency. This commonly occurs in low nitrogen, high fiber forage diets. If N is supplemented then DMI often increases dramatically (NRC, 1996). The NRC also says that with forages fine grinding can increase intake, this is presuming that this will cause an increase in digesta passage rate and thus an increase in DMI. Pelleting and grinding forages increased rate of passage and depressed ruminal digestion

(Patterson et al., 1994). Comparatively coarsely chopped forage had very few adverse effects on DMI, milk production, and ruminal fermentation (Patterson et al., 1994).

Intake in the ruminant animal is under the control of one of two different systems depending on the characteristics of the diet (Waldo, 1986). Highly digestible and more energy dense diets are primarily under the control of the nutritional need of the animal. Intake of diets that are less digestible and have less energy, like forages, are under the physical control of and limited by the space of the GI tract (Waldo, 1986).

Loya-Olguin et al. conducted research into the effects of slice baling on the feeding value of alfalfa hay in receiving diets and finishing diets in feedlot cattle in 2008. Slice baling was described as a process in which the hay is chopped to an average length of 7.6 cm after sun curing but prior to baling. Newly received cattle were fed a receiving ration for a 28 day period that contained alfalfa hay that had either been slice baled or ground to pass through a 5.08 cm screen. Cattle that were fed the slice baled hay had greater Final BW ($P < 0.01$) which was the result of greater ADG ($P < 0.001$), and G:F ($P < 0.002$) (Loya-Olguin et al., 2008). There were no significant differences between DMI of slice baled or ground rations found by Loya-Olguin et al. at 2.69 and 2.68 kg/steer respectively ($P < 0.57$) (2008). These results reinforce Patterson et al. (2004) in that forages that are finer textured have an increased passage rate and thus lower digestibility.

In another experiment Woodford et al. also researched the effects of forage physical form on production in dairy cows (1986). In this experiment cows were assigned to one of four diets that consisted of concentrate and chopped alfalfa hay of one of four lengths. The mean particle lengths (MPL) for the four different diets were: 1.0, 0.75, 0.50, and 0.25 cm. The results of this trial differed from others of similar design. Woodford et al. found that MPL of a diet had no significant effects on total DMI, chewing time, milk yield, and change in BW (*P* >0.05) (1986). Also, no differences were found between treatments for digestibility of DM, CP, NDF, ADF as well as rate of passage (*P* >0.05) (Woodford et al., 1986).

Jaster and Murphy (1983) conducted an experiment feeding alfalfa hay diets that included three physical forms: long, coarsely chopped, and finely chopped. A 3x3 Latin square experiment in which 18 Holstein heifers, housed in stanchions, were fed free choice of one of the three hay types for 21-day periods and intake was recorded each day. They found that intake was greater when heifers were offered either coarse or finely chopped hay versus long hay (*P* < 0.06). However there was no statistical difference between DMI of the two chopped hay forms. Additionally, heifers consuming long hay had higher digestibility of DM, NDF, hemicelluloses, and CP (*P* < 0.06) compared to those consuming either of the two chopped hays (Jaster and Murphy, 1983).

In an experiment that evaluated hay feeding strategies on feed sorting behavior in dairy heifers Hoffman fed five different diets with varying forms of chopped and long hay that were mixed in or top dressed to developing dairy heifers. 80 head of heifers were randomly assigned to one of five treatments in which the diet had one of the following forms of hay included in it: 1) long hay in a total mixed ration (TMR), 2) bale cut hay in a TMR, 3) chopped hay in a TMR, 4) long hay top dressed on a ration, and finally 5) bale cut hay top dressed on a ration. The study resulted in the heifer that were offered rations that were top dressed with either long hay or bale cut hay actually consumed less per day than the other three TMR rations. Hoffman and others found that the heifers in the study preferentially selected to consume particles of fine size over particles of coarse size. These results suggest that the incorporation of either long hay or bale cut hay into a TMR would be preferred over top dressing hays over a ration due to a potential DMI depression and increased sorting of forages when hay is top dressed.

Adams et al. had mixed results with their similar studies related to feeding chopped hay to dairy cattle. They fed chopped hay ad libitum to dairy cows and heifers and found in their trial that reducing forage particle length had no effect on DMI, milk production, DM or fiber digestibility (1987).

Chemical Form of Forage

The chemical make up of forage can greatly increase or decrease DMI by an animal. Feed intake is a key component to production be it meat, milk or wool. DMI has been closely associated with Neutral Detergent Fiber (NDF) concentration of the diet (Ruiz et al., 1995).Dairy cows require sufficient amount of dietary NDF to maintain rumen function and maximize milk yield (Oba et al., 1999). Ruiz et al. also reported that NDF concentration is thought to be negatively related to the energy concentration of feeds and positively related to the gut fill effect of the diet. An experiment was conducted to determine the effects of increasing dietary NDF concentrations on DMI and milk production in lactating dairy cows. As dietary NDF concentration increased DMI decreased from 3.69 to 3.35% as a percentage of body weight (BW) (Ruiz et al., 1995). Additionally, milk production decreased from 23.0 to 21.7 kg/d as diet NDF concentration increased (Ruiz et al., 1995). Digestibility of NDF is important because forage NDF varies widely in its degradability in the rumen and NDF digestibility influences animal performance greatly (Oba et al., 1999). The *Nutrient Requirements of Dairy Cattle* (NRC, 2001) states that at any particular NDF concentration in the diet a considerable range in DMI was observed and thus suggests that the source of NDF in the diet as affected by particle size, digestibility, and rate of passage from the reticulorumen affect DMI.

Supplement

Winter nutrition program for beef cows are often centered on low quality forages. These forages would include grazing dormant native grasses or feeding harvested forages in the form of hay. Both of these programs require the addition of a protein supplement to meet the requirements of the cow. The addition of monensin (MON, Rumensin 90®; Elanco Animal Health; Greenfield, IN) has been shown to decrease DMI while increasing feed efficiency (Clanton et al., 1981). Research into the effects of supplemental MON on beef cow weight and BCS change has been mixed (Turner et al., 1977; Lemenager et al., 1978; Clanton et al., 1981). In a 1988 review, Sprott et al., summarized that performance may not be affected by supplemental MON, but DMI was often reduced. Turner et al., found that DMI was not changed by the inclusion of supplemental MON ($P > 0.05$) (1977). In contrast, Walker et al., in 1980 found that DMI was reduced in cows fed increasing supplemental levels of MON ($P < 0.05$). The effects of MON supplementation on performance appear to be closely related to forage quality. Use of MON with low quality forages resulted in decreased DMI and improved feed conversion, while higher quality forages supplemented with MON resulted in increased weight and condition gains (Sprott et al., 1988). The effects of supplemental MON on apparent digestibility are limited to growing cattle studies. Dinius et al. found no differences in apparent digestibility of DM, CP, NDF or ADF between steers on a forage diet supplemented with M ($P > 0.10$) (1976). Similarly in 1981 Muntifering et al. reported no effect of supplementing beef steers on a largely concentrate diet with MON on apparent total tract OM, starch or ruminal, postruminal, or total tract CP digestibility ($P > 0.10$).

SUMMARY

With the current economic standing of the cattle industry producers need to have a full understanding of how to best manage their cost of production in their beef enterprise. This understanding cannot be limited to different methods for delivering hay to their herd, but must also touch on the factors that limit how much hay animals can consume. Additionally, prior to delivering hay to their cattle a producer must also understand the physical and chemical factors that are established as he produces that hay prior to feeding it. Understanding of moisture and its role in making hay, as well as the chemical components like NDF and ADF along with ADIN. Additionally a producer needs to pencil out the best storage system for their operation that will provide a secure place to protect their investment. Producers need a broad knowledge base of not only beef production but forage production as well to maximize productivity of their beef operation.

LITERATURE CITED

Adams, M. W., and R. L. Belyea. 1987. Effects of variety and particle size upon the utilization of fescue hay by lactating dairy cows and dairy heifers. J. Dairy Sci. 71:1275-1282.

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

Brasche, M. R., and J. R. Russell. 1988. Influence of storage methods on the utilization of large round hay bales by beef cows. J. Anim. Sci. 66:3218-3226.

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.

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.

Coblentz, W. K., J. E. Turner, D. A. Scarbrough, K.E. Lesmeister, Z. B Johnson, D. W. Kellogg, K. P. Coffey, L. J. McBeth, and J. S. Weyers. 2000. Storage characteristics and nutritive value changes in bermudagrass hay as affected by moisture content and density of rectangular bales. Crop Sci. 40:1375-1383.

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.)

Dinius, D. A., M. E. Simpson, and P. B. Marsh. 1976. Effect of monensin fed with forage on digestion and the ruminal ecosystem of steers. J. Anim. Sci. 42:229-234.

Goering, H. K., P. J. Van Soest, and R. W. Hemken. 1973. Relative suceptability of forages to heat damage as affected by moisture, temperature and pH. J. Dairy Sci. 56:137-143.

Hoffman, P. C., C. R. Simson, and K. J. Shinners. 2006. Evaluation of hay feeding strategies on feed sorting behavior of dairy heifers fed mock lactation diets. Prof. Anim. Sci. 22:71-79.

Huhnke, R. L. 1987. Large round bale alfalfa hay storage. Appl. Eng. Agric. 4:316-317.

Jaster, E. H. and M.R. Murphy. 1983. Effects of varying particle size of forage on digestion and chewing behavior of dairy heifers. J. Dairy Sci. 66:802-810.

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

Lechtenberg, V. L., W. H. Smith, S. D. Parsons, and D. C. Petritz. 1974. Storage and feeding of large hay packages for beef cows. J. Anim. Sci. 39:1011-1015.

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.

Loya-Olguin, F., L. Avendaño-Reyes, A. M. Encinias, D. A. Walker, N. A. Elam and S. A. Soto Navarro. 2008. Influence of slice baling on feeding value of alfalfa hay in receiving and finishing diets for feedlot cattle. J. Anim. Sci. 86:2749-2755.

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.

Muntifering, R. B., B. Theurer, and T. H. Noon. 1981. Effects of monensin on site and extent of whole corn digestion and bacterial protein synthesis in beef steers. J. Anim. Sci. 53:1565-1573.

National Research Council. 1996. Nutrient requirements of beef cattle. 7th Rev. Ed. Natl. Acad. Sci., Washington, DC. National Research Council. 2001. Nutrient requirements of dairy cattle. 7th Rev. Ed. Natl. Acad. Sci., Washington, DC.

Oba, M. and M. S. Allen. 1999. Evaluation of the importance of the digestibility of neutral detergent fiber from forage: effects on dry matter intake and milk yield of dairy cows. J. Dairy Sci. 82:589-596.

Patterson, J. A., R. L. Belyea, J. P. Bowman, M. S. Kerley, and j. E. Williams. 1994. The impact of forage quality and supplementation regimen on ruminant animal intake and performance. Page 59 in Forage Quality, Evaluation, and Utilization. G. C. Fahey ed. American Society of Agronomy, Inc. Madison, WI.

Ruiz, T. M., E. Bernal, and C. R. Staples. 1995. Effect of dietary neutral detergent fiber concentration and forage source on performance of lactating cows. J. Dairy Sci. 78:305-319.

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.

Turner, H. A., R. J. Raleigh, and D. C. Young. 1977. Effect of monensin on feed efficiency for maintaining gestating mature cows wintered on meadow hay. J. Anim. Sci. 44:338-342.

Volesky, J. D., D. C. Adams, and R. T. Clark. 2002. Windrow grazing and baled hay feeding strategies for wintering calves. J. Range Manage. 55:23-32.

Waldo, J. R. 1986. Effect of forage quality on intake and forage – concetrate interactions. J. Dairy Sci. 69:617-631.

Walker, P. M., B. A. Weinchenthal, G. F. Cmarik. 1980. Efficacy of monensin for beef cows. J. Anim. Sci. 51:532-538.

Woodford, J. A., N. A. Jorgensen, and G. P. Barrington. 1986. Impact of dietary fiber and physical form on performance of lactating dairy cows. J. Dairy Sci. 69:1035-1047.

CHAPTER III

EFFECTS OF BALE FEEDER TYPE AND PROCESSING ON HAY WASTE, INTAKE, AND PERFORMANCE OF BEEF CATTLE

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ABSTRACT: Three experiments were conducted to evaluate the effects of hay processing and bale feeder type on hay waste, intake, and performance of beef cattle. Experiment 1 used 64 crossbred gestating beef cows with two levels of hay processing methods (long stemmed [LONG] and pre-cut [PCUT]) and two hay feeder types (conventional ring feeder [RING] and cone [CONE]). There was less hay waste from LONG than PCUT (8.3 % and 13.0 %, P = 0.003). CONE feeders were had less waste than RING feeders (6.7 % vs. 14.5 %, P = 0.0002). There was little evidence of differences in DMI due to hay or feeder type. The second experiment utilized 96 crossbred, weaned calves in assessing the effect of hay type (LONG vs. PCUT) on post

weaning performance. No practical differences were found between the two hay types. Calves fed the LONG hay had an ADG of 0.83 kg/d, compared to calves fed the PCUT hay that had an ADG of 0.81 kg/d (P = 0.65). In the final experiment, cow/calf pairs were used to evaluate the effect of hay type on hay waste and intake. All pastures used modified cone bale feeders. LONG hay had less waste than PCUT (4.99% vs. 12.87%, $P = 0.03$). There was little evidence of differences between hay types in DMI ($P = 0.66$). Throughout all experiments the conclusion that hay type and feeder type can have a dramatic effect on hay utilization by beef cattle and thus the potential for profitability.

Key Words: beef cattle, hay feeding, hay feeders, hay waste, pre-cut hay

INTRODUCTION

Harvesting forage during the summer months for delivery during winter is a common practice for most cow/calf producers. Survey data from Oklahoma State University found that 45% of all producer respondents fed hay between 91 and 120 d each winter (Vestal, 2007). When evaluating standardized performance analysis, hay costs are a major contributor to the cost of production in cow/calf operations. Large round bales are the form of hay typically provided to cows in the Southern Great Plains and Midwest during the winter months.

Numerous round bale feeding methods are used including unrolling, feeding whole bales with no hay ring, and feeding whole bales with the use of some type of a hay feeder or ring. In one study, hay fed with no ring feeder resulted in 45% hay waste, while waste was limited to 9% when a ring feeder was used (Bell and Martz, 1973). However, dozens of hay ring designs are on the market today ranging in cost from approximately $200 to $2500. Buskirk et al. (2003) compared four different round bale feeder types and found that cone feeders were the most effective at limiting hay waste (3.5%) followed by the typical hay ring (6.1%). These scientists also found that, with the typical hay ring, cows more often reached over the top to consume hay as compared to the cone model where cows must access hay through the side.

In addition to feeder type, it is also of interest to determine if hay particle size influences hay DMI, wastage, or animal performance. Processing of dry roughage has been shown to increase particulate passage rate, resulting in an increase in DMI (NRC, 1996). If hay could be coarsely cut or chopped during the baling process, hay intake and thus, animal performance may be improved with minimal increase in cost due to processing. Therefore, the objective of these experiments was to determine the effects of hay feeder type and hay processing on hay utilization.

MATERIALS AND METHODS

Hay Production

Four lots of first cutting hay, three which were prairie hay which contained primarily a mix of big bluestem, little bluestem, switch grass, and Indian grass, and one which contained primarily common bermudagrass, were baled on July 14 and 15, 2009. Prairie hay was used in experiment one and three, while the bermudagrass hay was used in experiment two. Hay was baled either by a conventional round baler (LONG; Model 568; John Deere, Ottumwa, IA) or another of the same baler that was fitted with a mechanism to cut the hay as it was fed into the baler (PCUT). Samples of both hay processing methods were hand measured to determine particle length. Particle length of LONG and PCUT hay was 25.4 ± 2.8 and 15.5 ± 6.4 cm respectively. Both balers operated in the same hay meadow at the same time to insure that hay quality was similar among treatments. The round bales were removed from the field within 1 wk of baling and stacked on the ground in rows by hay meadow until fed. Two weeks prior to the initiation of the experiments bales were sampled for nutritive analysis. The forage quality analysis for native range hay was: 93.9% DM, 6.29% CP, 42.56% ADF, 69.74% NDF, and 0.13% ADIN as a % DM. The Bermudagrass hay forage analysis was: 93.7% DM, 11.04% CP, 38.43% ADF, 73.8% NDF and 0.14% ADIN as a % DM. The bales were then resorted into feeding order (within source) based on NDF and ADIN values. Ruiz et al. (1995) reported that NDF concentration is negatively related to the energy concentration of feeds and positively related to the gut fill effect of the diet, potentially limiting DMI. Additionally, Coblentz et al. (2000) found that ADIN was positively related to incidences of spontaneous heating within round bales. The feeding order within treatments was designed to insure that treatment groups were receiving hay of similar nutritive value.

Experiment 1

Sixty-four crossbred beef cows (590 ± 59 kg) in late gestation were used in a 4 × 4 Latin square experiment to determine the effects of hay processing prior to baling and round bale feeder type on hay waste and intake. Sixteen cows were randomly assigned to one of four previously grazed 0.81 ha pastures that each contained a 12.2 × 7.625 m^2 concrete feeding pad. The experiment was set up with a 2 × 2 factorial treatment arrangement. The pastures were assigned one of two different round bale feeder types: cone (CONE) or a conventional ring (RING) feeder (Figure 3.1). The diameter of the RING was 2.44 m, with an overall height of 130.2 cm (Model Super-10 Bale Feeder; Franklin Industries, Montecello, IA). The RING feeder had 16 individual feeding stations that were 48.3 cm wide. The CONE feeder was simply the RING feeder with a cone insert placed inside of it (Model Super-10/CY-8 Unit; Franklin Industries, Montecello, IA.). The pastures were also assigned one of two bale treatments: LONG or PCUT. The treatments were rotated between each pasture so that each pasture received each treatment combination once during the experiment.

During a collection period, the cows were adapted to the treatment combination for 10 d. They had ad libitum access to the hay and received 0.91 kg/hd of 30% CP supplemental dried distiller's grains with soluble (DDGS) daily. On d 10 the remaining hay in the feeder was removed and all manure was cleaned off of the feed pad. After cleaning, the feeder was put back onto the feed pad and a fresh bale was weighed and placed into the feeder. Waste was defined as hay outside of the feeder and orts were defined as hay inside of the feeder. Waste was sorted into manure contaminated and uncontaminated groups and different dry matter values were calculated for each of the groups to better determine the amount of waste for each bale. Waste was collected, weighed and sampled at 24 and 48 h after initial placement of the bale into the feeder. Orts were collected, weighed, and sampled 48 h after the initial placement of the bale into the feeder. Fecal grab samples were collected in paper cups twice daily at 0800 and 1600 on d11 through 14 during the collection period to predict fecal output from acid detergent insoluble ash (ADIA) concentration. After the collection period was complete the feed pads were again cleaned and fresh bales were placed in the feeders and the process was repeated for another 48 h, providing two replicates of each treatment combination from each pasture. Once the second replicate for the treatment combination was complete the feed pads were again cleaned and the treatments were rotated to a different pasture and a new adaption period was started.

Data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC), with pasture considered the experimental unit. The model statement contained fixed effects hay type (LONG and PCUT) and feeder type (RING and CONE). The random statement included pasture and period. Least squares means were separated using the PDIFF option of SAS. Treatments were determined to be different at $\alpha = 0.05$.

Experiment 2

Ninety-six crossbred weaned calves (260 ± 29 kg) were used to conduct a randomized complete block designed experiment to evaluate the effect of hay processing on the post-weaning performance of beef calves. The calves were ranked by weight within gender and randomly allotted to 1 of 8 pens equipped with a RING feeder and automatic waterer. Each pen was then randomly assigned one of two hay type treatments, LONG or PCUT, for the duration of the experiment. This supplied 2 pens of each hay type within each gender. Calves were weighed on d 0, 1, 44 and 45 and the average of d 0 and 1 were used to calculate calves' beginning weight, while the weights from d 44 and 45 were averaged to calculate ending weight. Ad libitum access to the hay was provided along with 2.27 kg of 30% CP DDGS per head daily.

Calf performance data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). Pasture was considered the experimental unit. The model statement contained fixed effects of hay type (LONG and PCUT), and the random statement included pasture. Least squares means were separated using the PDIFF option of SAS. Treatments were determined to be different at $\alpha = 0.05$.

Experiment 3

Forty eight crossbred, lactating cows and their calves were used in a randomized complete block design to assess the effect of bale processing on hay waste and intake. Pairs were ranked by weight so that cow weight, calf weight and calf age were equal across all pastures. The average pair weight was 650.58 ± 4.49 kg. Twelve pairs were allotted to one of the four pastures used in Experiment 1. Pairs remained in the same paddock throughout the experiment. Hay treatments, LONG and PCUT, were randomly allotted to two of the four pastures. All pastures used modified cone bale feeders (Bextra Heavy, Lienimann Management Productions, LLC., Princeton, NE) shown in Figure 3.2. Pairs had ad libitum access to the hay and were provided with 1.36 kg of 30% CP DDGS daily. There was a 10-day adaptation for the pairs to become familiar with the paddocks as well as the modified cone feeders being used in the experiment. Upon completion of the adaptation period each collection period was 48 h long. Similarly to Experiment 1 the feed pads were cleaned of manure and hay and a fresh bale was placed in the feeders. Waste was collected, weighed, and sampled at 24 and 48 h. Orts were collected, weighed, and sampled at 48 h. Upon the completion of the collection period the feed pads were cleaned and a fresh bale was provided to begin the next collection period. This was done for a total of four replications.

Data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC), with pasture considered the experimental unit. The model statement contained fixed effects hay type (LONG and PCUT), and the random statement included pasture with period being a repeated measure. Least squares means were separated using the PDIFF option of SAS. Treatments were determined to be different at $\alpha = 0.05$.

Sample Analysis

Initial bale core, uncontaminated and contaminated waste, and orts subsamples were collected in paper bags. All forage and fecal samples were immediately dried to determine DM (oven dried at 50°C until no further weight loss). Following drying, samples were ground through a Wiley Mill (Model 4, Thomas Scientific, Sweedesboro, NJ) using a 2 mm screen for initial bale core, ort, dry waste and wet waste samples, and a 1 mm screen for fecal samples and stored for further analysis. Initial bale cores, waste, ort and fecal samples were analyzed for NDF and ADF (Ankom Tech Corp, Fairport, NY), ash (combusted 6-h in a muffle furnace at 500°C), and CP (% N × 6.25; TruSpec CN, LECO Corporation, St. Joseph, MI 49085). Acid detergent insoluble nitrogen (ADIN) as a % CP was determined by analyzing ADF residues for CP (% N × 6.25; TruSpec CN, LECO Corporation, St. Joseph, MI 49085). ADIA contents in initial bale cores, waste, orts, and fecal samples were determined by ashing ADF residues in a muffle furnace at 500 ºC for 8 h.

RESULTS AND DISCUSSION

Experiment 1

The effects of hay processing and feeder type on hay waste are shown in Table 3. 1. There was little evidence of hay type by feeder type interaction ($P = 0.50$); therefore, data are presented for main effects only. Feeding LONG hay resulted in 36.2 % less waste when compared to feeding PCUT hay ($P = 0.003$). Observation of the PCUT bales showed that the shorter particle length caused the bales to deteriorate faster. The increased particle length of LONG bales permitted the bales to hold the bale form longer throughout the collection period and remain inside the feeder.

Use of RING feeders resulted in 53.8% more ($P = 0.0002$) waste compared to CONE feeders. This is consistent with the findings of Buskirk et al. (2003) who found that CONE feeders tended to have less hay waste than RING feeders, yielding 3.5 and 6.1%, waste respectively ($P = 0.06$). Comerford et al. (1994), also found that CONE feeders were more effective than RING feeders at reducing waste reporting losses of 1.9% and 8.0%, respectively. In the current experiment the positioning of the bale off of the ground and centrally positioned by the CONE feeders allowed cows to feed while their heads remained inside the feeder. Cows had to reach to access hay in CONE feeders. This allowed any hay that was pulled out from the bale or dropped during the process of chewing to fall inside of the protected portion of the sheeted bottom of the CONE feeder. Shultheis and Hires (1982) found that the combination of a slanted bar head gate and a pusher bar between the slanted bar head gate and the hay, designed to make cattle reach for hay reduced waste ($P < 0.01$). The slanted head gates used alone and a vertical bar head gate and pusher bar combination resulted in 16.41 % and 12.60 % hay waste, respectively. However, when used in conjunction, a slanted bar head gate and a pusher bar reduced waste to 9.20 % ($P < 0.01$). With regard to the RING feeder in the current experiment, the placement of the bale, especially during the first 24 h of access by the cows, did not allow for the free space for the cows heads as with the CONE feeder. Hay could escape the ring feeders more easily due to the close proximity of bales with the outside of the RING feeder.

The effects of hay processing and feeder type on hay intake and apparent digestibility are reported in in Table 3.2. There was little evidence of hay processing method × feeder type interaction (P = 0.49). Hay processing method had little effect on cow DMI (P = 0.53).DMI was calculated as :((initial bale weight offered -waste - orts weight) / cows in the pen) (n=16). Conversely, Jaster and Murphy (1983) observed that heifers offered a diet of coarsely or finely chopped hay compared to long hay tended to have increased DMI (P < 0.06). No differences in DMI between the two chopped diets were recorded (Jaster and Murphy, 1983). Additionally, in the current experiment, feeder type had little effect on DMI (P = 0.23). The DMI as a percent of cow BW of the current experiment is similar to those of previously reported results (Bell and Martz, 1973; NRC, 1996; Buskirk et al., 2003). Hay processing method and feeder type had little effect on apparent DM and OM digestibility ($P > 0.05$). This is similar to results reported by Adams et al. (1987), in which chopped hay was fed ad libitum to dairy cows and heifers and found that reducing forage particle length had no effect on DMI, milk production, as well as DM or fiber digestibility. Conversely, Jaster et al., reported in 1983 that heifers consuming long hay had higher digestibility of DM, NDF, hemicelluloses, and CP ($P <$ 0.06) compared to those consuming either of the two chopped hays.

Experiment 2

The effects of hay type on post weaning performance of beef calves are presented in Table 1.3. Post weaning performance, measured by ADG, of calves was not different between the two hay types (P = 0.65). Lofgreen and Kiesling (1985) reported similar gains to those of the current study by calves fed grass hay along with a protein supplement for a 42 d receiving period. As seen in Experiment 1, intake was not affected by hay processing method. It appears that, if the only difference between treatments is hay particle length, then performance would be expected to be similar.

Experiment 3

The effects of hay type on hay waste when prairie hay was fed to fall calving cows and their calves, can be seen in Table 1.4. Hay waste was again significantly different between hay processing mthods in this study and similar to that from Experiment 1 where dry pregnant cows consumed LONG or PCUT prairie hay. LONG hay yielded 61.2% less waste than the PCUT hay (P = 0.03). The structural integrity of the bales of both the LONG and PCUT bales probable influenced the waste differences. The short particle length of the PCUT bales prevented the bales from holding together upon removal of net wrap from the bale prior to feeding. The structure of the LONG bales provided by the longer particle length allowed the bales to maintain their form well into the feeding period. The modified cone used in the experiment was consistent among all paddocks. The ranking of the two hay processing methods with regard to waste was consistent with the results from Experiment 1.

The effects of hay type on DMI can be seen in Table 1.5. Similar to Experiment 1, there were no significant differences between the two hay types in DMI in this experiment (P = 0.66). DMI was calculated as: ((initial bale weight -waste - orts weights) / number of cow-calf pairs in the pen) (n = 12). When evaluated as DMI as a percentage of pair weight, no differences were found between the two hay types (P = 0.71). These results are consistent with previous research evaluating the effects of particle length on DMI (Jaster and Murphy, 1983).

Implications

Processing (cutting or chopping) hay during the baling process has potential to improve efficiency by eliminating the need to process baled hay prior to incorporation in a total mixed ration (TMR). Beef cattle enterprises that frequently use processed hay in TMRs include feed yards, back grounding yards, receiving yards and some livestock markets. In this experiment, we evaluated the use of PCUT hay in enterprises where unprocessed hay is traditionally fed to cows and yearlings. While we discovered that feeding PCUT hay in a RING feeder results in more hay waste, this waste can be minimized by utilizing a commercially available CONE feeder.

LITERATURE CITED

Bell, S. and F. A. Martz. 1973. Res. Rep. Univ. of Missouri Agric. Exp. Sta. Columbia, MO.

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.

Coblentz, W. K., J. E. Turner, D. A. Scarbrough, K. E. Lesmeister, Z. B. Johnson, D. W. Kellogg, K. P. Coffey, L. J. McBeth, and J. S. Weyers. 2000. Storage characteristics and nutritive value changes in bermudagrass hay as affected by moisture content and density of rectangular bales. Crop Sci. 40:1375-1383.

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.).

Jaster, E. H., and M. R. Murphy. 1983. Effects of varying particle size of forage on digestion and chewing behavior of dairy heifers. J. Dairy Sci. 66:802-810.

Lofgreen, G. P., and H. E. Kiesling. 1985. Effects of receiving diets on compensatory gains of stressed cattle. J. Anim. Sci. 61:320-328.

National Research Council. 1996. Nutrient requirements of beef cattle. 7th Rev. Ed. Natl. Acad. Sci., Washington, DC.

Ruiz, T. M., E. Bernal, and C. R. Staples. 1995. Effect of dietary neutral detergent fiber concentration and forage source on performance of lactating cows. J. Dairy Sci. 78:305-319.

Schultheis, R. A. and W. G. Hires. 1982. Self feeding headgates for large round hay bales. ASABE. 25:1553-1555.

Vestal, M., W. Clement, D. Doye, D. Lalman. 2007. Cow-calf production practices in Oklahoma Part 1. http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-4570/AGEC-245web.pdf Accessed July 10, 2010.

Table 3.1. Effects of hay processing and feeder type on hay waste by gestating beef cows

	Hay[1]			Feeder[2]			*P*-value[3]	
Item	LONG	PCUT	SEM[4]	RING	CONE	SEM[4]	Hay	Feeder
n	16	16		16	16			
Waste, % of bale wt[5]	8.3	13.0	1.1	14.5	6.7	1.1	0.003	0.0002

[1] LONG = long stemmed hay; PCUT = Pre-cut hay.

[2] RING = conventional ring hay feeder; CONE = cone hay feeder.

[3] Observed significance levels for main effects.

[4] SEM of the Least squares means.

[5] Hay waste expressed as a percentage of mean bale wt.

Table 3.2. Effects of hay processing and feeder type on hay intake and apparent digestibility of gestating beef cows

	Hay[1]			Feeder[2]			*P*-value[3]	
Item	LONG	PCUT	SEM[4]	RING	CONE	SEM[4]	Hay	Feeder
N	16	16		16	16			
DMI, kg/hd/d	10.45	10.76	0.28	10.31	10.91	0.28	0.44	0.15
DMI, % of BW[5]	1.77	1.82	0.05	1.75	1.85	0.05	0.46	0.17
Apparent Digestibility, %								
DM	63.28	64.18	1.25	63.83	63.63	1.25	0.61	0.91
OM	65.88	66.91	1.14	66.42	66.37	1.14	0.53	0.98

[1] LONG = long stemmed hay; PCUT = Pre-cut hay.
[2] RING = conventional ring hay feeder; CONE = cone hay feeder.
[3] Observed significance levels for main effects.
[4] SEM of the Least squares means.
[5] DMI expressed as a percentage of initial mean BW.

Table 3.3. Effects of hay processing on post weaning performance of beef calves

	Hay[1]			
	LONG	PCUT	SEM[2]	*P*-value[3]
n	8	8		
Initial wt, kg	260.46	260.35	0.55	0.90
Final wt, kg	298.02	296.68	2.06	0.67
Total gain, kg	37.56	36.32	1.76	0.65
ADG, kg/d	0.83	0.81	0.04	0.65

[1] LONG = long stemmed hay; PCUT = Pre-cut hay.

[2] SEM of the Least squares means.

[3] Observed significance levels for main effects.

Table 3.4. Effects of hay processing on hay waste of cow/calf pairs

	Hay[1]			
Item	LONG	PCUT	SEM[2]	*P*-value[3]
n	16	16		
Waste, % of bale wt[4]	4.99	12.87	1.06	0.03

[1] LONG = long stemmed hay; PCUT = Pre-cut hay.

[2] SEM of the Least squares means.

[3] Observed significance levels for main effects.

[4] Hay waste expressed as a percentage of mean bale wt.

Table 3.5. Effects of hay processing on hay intake of cow/calf pairs

	Hay[1]			
Item	LONG	PCUT	SEM[2]	*P*-value[3]
n	16	16		
DMI, kg/Pair/d	12.09	12.48	0.53	0.66
DMI, % of PW[5]	1.87	1.91	0.08	0.71

[1] LONG = long stemmed hay; PCUT = Pre-cut hay.
[2] SEM of the Least squares means.
[3] Observed significance levels for main effects.
[4] DMI expressed as a percentage of initial mean cow/calf pair wt (PW).

(a) (b)

Figure 3.1. Conventional ring (a) and cone (b) bale feeders used in Experiment 1.

Figure 3.2. Modified cone bale feeders used in Experiment 3.

CHAPTER IV

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

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ABSTRACT: The effects of feeder type and supplemental monensin on hay utilization in beef cows was conducted using 56 crossbred beef cows (BW= 494 ± 50 kg; BCS= 5.2 ± 0.5) in a split-plot with a completely randomized design with supplement treatment as the mina unit and a feeder design as the subunit. The main unit included two supplement treatments, while the subunit included four hay feeder designs. Supplement treatments included a 36% CP cottonseed meal based pellet with 0 (CONT; control) or 200 mg/head of monensin (MON), fed at a rate of 1.36 kg/ head daily. Feeder design treatments included a conventional open bottomed steel ring (OBSR), a sheeted bottomed steel ring

(RING), a polyethylene pipe ring (POLY), and a modified cone feeder (MODC). Cows were weighed and allotted based on BW to one of four previously grazed 2.0 ha paddocks equipped with a 12.2 x 7.6 m^2 concrete feeding pad. Hay waste was significantly affected by hay feeder design with 5.6, 20.6, 21.5, and 12.7 % waste for MODC, OBSR, POLY, and RING respectively ($P < 0.01$). Supplement had no effect on hay waste ($P = 0.79$). There was a trend for DMI to differ among feeder types ($P = 0.12$) but not for supplement treatments ($P = 0.45$). Supplementing with MON resulted in improved cow performance with regard to final BCS, weight gain, BCS gain and ADG ($P < 0.05$). Furthermore, apparent digestibility was increased due to supplemental MON for DM, OM, NDF, and ADF ($P < 0.05$). Apparent digestibility of CP tended to be different for cow supplemented with MON ($P = 0.08$). The results of this study indicate that feeder design can greatly impact the amount of hay needed during a feeding period. DMI was not affected by supplementation of MON or feeder design. Furthermore, supplemental MON in this study positively altered apparent digestibility. The combination of hay savings from feeder design and increased apparent digestibility can have a dramatic effect on hay utilization by beef cows and thus on potential profitability.

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

INTRODUCTION

Harvesting feed during the summer months for delivery during the winter is a common practice for most cow/calf producers. Costs associated with nutrition account for between 40-60 % of the annual budget of a cow/calf operation (Bevers, 2010; Miller et al, 2001). Survey data from Oklahoma State University found that 45% of all producer respondents fed hay between 91 and 120 d each winter (Vestal, 2007). The large round bale is the form of hay typically provided to cows in the Southern Great Plains and in the Midwest during the winter months. There are several methods of delivering free choice hay to cows, including unrolling, feeding whole bales with no hay ring and feeding whole bales with the use of some type of a hay feeder or ring as well as utilizing a PTO-driven bale processor. The use of hay rings has been shown to decrease hay loss from 45 to 9% when feeding round bales (Bell and Martz, 1973), deeming hay rings a practical way to control hay waste. However, there are dozens of hay ring designs on the market today ranging from approximately \$100 to \$2500. Buskirk et al. (2003) compared four different round bale feeder types and found that the cone feeder was the most effective at managing hay waste followed by the typical hay ring, with 3.5 and 6.1% waste respectively. Currently in Oklahoma the most popular style of round-bale feeder is some variety of the basic ring, with different cone type feeders becoming increasingly popular (Sexten et al., unpublished data). Results of a poll conducted in December of 2010 indicated that 68.3 % of respondents ranked the use of a “ring type” feeder in combination with large round bales of hay as the most popular form of hay delivery (Sexten et al., unpublished data). When asked about the most popular type of large round bale feeder 68.3 % of respondents said that an economy open bottomed steel ring feeder was the most popular (Sexten et al., unpublished data). Next was a metal ring with a closed or sheeted bottom at 26.8 %, followed by an open bottomed polyethylene pipe feeder with 4.9 % (Sexten et al., unpublished data). When asked about specific options on hay feeder that producers preferred, sheeted bottom and slated stations were the most common response (Sexten et al., unpublished data). 61 % of respondents ranked cost as the most important factor when selecting a feeder to purchase (Sexten et al., unpublished data). The weight/ease of handling ranked second at 34.1 %, followed by feeder quality/durability at 4.9 % (Sexten et al., unpublished data).

Supplementation of cows with monensin (MON, Rumensin 90®; Elanco Animal Health; Greenfield, IN) has been shown to decrease DMI (Lemenager et al., 1978). Clanton et al. in 1981 also found that supplemental MON decreased DMI while increasing feed efficiency. However, results of research into the effect of supplemental M on weight and BCS change have been mixed (Turner et al., 1977; Lemenager et al., 1978; Clanton et al., 1981). In a 1988 review Sprott et al. summarized that performance may not be affected by supplemental MON, but DMI was often reduced. The effects of supplemental MON appears to be closely related to forage quality being consumed. Supplemental MON in conjunction with low quality forage resulted in lower DMI and improved feed conversion, while higher quality forages when paired with supplemental MON resulted in increased weight and BCS gains (Sprott et al., 1988). Therefore, it is the objective of this study to determine the effects of popular hay feeder types and supplementation with monensin on hay waste, hay intake and animal performance.

MATERIALS AND METHODS

Animals and Diet

This experiment was conducted at the OSU Range Cow Research Center; North Range Unit located approximately 16 km west of Stillwater, Oklahoma in accordance with an approved Oklahoma State University Animal Care and Use Committee protocol. Fifty six crossbred beef cows (BW= 494 ± 50 kg; BCS= 5.2 ± 0.5) were used in a split-plot with a completely randomized design. The main unit treatments included two supplement treatments, while the subunit treatments included four hay feeder designs. Cows were weighed and allotted based on BW to one of four previously grazed 2.0 ha paddocks equipped with a 12.2 x 7.6 m^2 concrete feeding pad. Paddocks were randomly assigned to one of two supplement treatments which included 1.36 kg/ head daily of a 36% CP cottonseed meal based pellet with 0 (CONT; control) or 200 mg of MON. The nutrient composition of the hay fed is shown in Table 4.1.

Hay Feeders

The four bale feeder designs used in the experiment can be seen in Figure 4.1. Each paddock was initially randomly assigned one of the four feeder designs which included: a conventional open bottomed steel ring (OBSR), a sheeted bottomed steel ring (RING), a polyethylene pipe ring (POLY), and a modified cone feeder (MODC). Feeders were selected based on polling results of county and regional extension specialists (Sexten et al., unpublished data). The diameter of the OBSR was 2.44 m, with an overall height of 101.6 cm. The diameter of the RING was 2.44 m, with an overall height of

130.2 cm. The POLY feeder diameter was 2.36 m, with an overall height of 113 cm. The diameter of the MODC was 2.66 m and had an overall height of 144.8 cm. The RING feeder had 16 individual feeding stations that were 48.3 cm wide. The remaining three feeders did not have individual feeding stations.

Collection Period

Four collection periods were completed during the experiment. Two bales were fed during each collection period within each paddock. Cows were offered ad libitum access to a fresh bale and adapted to the feeder treatment during the duration required to consume 85 % of the bale. Upon consuming 85 % of the bale all remaining hay within the feeders (orts) was removed along with any other foreign material on the concrete pads. Once the concrete pads were clean the feeder was returned and a fresh bale was placed in the feeder for collection. Collection for one bale lasted 96 h after the bale was placed in the feeder. After the first 96 h collection period the concrete pads were again cleaned and the second bale of the period was placed in the feeder for collection the following 96 h. Bales were weighed and three core samples were taken (Colorado Hay Probe; Nasco, Fort Atkinsin, WI) for analysis and all twine was removed prior to being placed in the feeder. Waste was collected daily at 1500 h from around each feeder at 24, 48, 72 and 96 h. Waste was defined as any hay outside of the feeder. Waste was sorted into dry and wet subgroups to allow for differences in dry matter, weighed and subsampled for further analysis. Special attention was given to avoid the collection of manure or other foreign materials with the waste samples. After completing waste collection on h 96, orts were collected from within the feeder. Fecal grab samples were collected daily at 0800 and 1600 h. Subsamples of both dry and wet waste and orts as well as fecal samples were dried to determine DM (oven dried at 50°C until no further weight loss). Following drying samples were ground through a Wiley Mill (Model 4, Thomas Scientific, Sweedesboro, NJ) using a 2 mm screen for initial bale core, ort, dry waste and wet waste samples, and a 1 mm screen for fecal samples and stored for further analysis. Waste, ort and fecal samples were analyzed for neutral detergent fiber (NDF) and acid detergent fiber (ADF) (Ankom Tech Corp, Fairport, NY), Ash (combusted 6-h in a muffle furnace at 500°C), and CP (% N x 6.25; TruSpec CN, LECO Corporation, St. Joseph, MI 49085). Acid detergent insoluble ash (ADIA) contents in initial bale cores, dry waste, wet waste, orts, and fecal samples were determined by ashing ADF residues in a muffle furnace at 500^{o}C for 8 h. Apparent digestibility of

Statistical Analysis

Hay waste, cow intake data and apparent digestibility were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC), with pasture considered the experimental unit. The model statement contained supplement (CONT an MON; fixed), paddock in supplementation (random), feeder type (MODC, OBSR, POLY, and RING; fixed) supplement × feeder type (fixed) and feeder type ×paddock in supplement (random). Period effects were assumed to be negligible.

Cow performance data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC), with pasture considered the experimental unit. The model statement contained the fixed effect of supplement (CONT and MON), and the random statement included paddock.

All Least squares means were separated using the PDIFF option of SAS. Treatments were determined to be different at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Hay Waste and Intake

The effects of supplement treatment and feeder treatment on hay waste are shown in Table 4.22. There were no supplement × feeder treatment interactions on hay waste ($P = 0.18$). Supplement did not affect hay waste ($P = 0.79$). There were significant differences in hay waste between all feeders except OBSR and POLY ($P < 0.01$). The MODC feeder was the most efficient feeder treatment, resulting in 56.2% less wasted hay than the next closest feeder ($P < 0.01$). The RING feeder resulted in over twice the amount of waste as the MODC. However, the RING feeder wasted less hay than both the OBSR and the POLY feeders ($P < 0.01$). Both the OBSR and the Poly feeder wasted more hay than the MODC feeder ($P < 0.01$). However, no differences were found between the OBSR and POLY feeders ($P = 0.62$). These results are similar to those of Buskirk et al., who in 2003 reported that feeding large round bales with a cone style feeder yielded the least amount of waste when compared to a traditional sheeted bottomed ring, at 3.5 and 6.1 % waste respectively. Results from Landbolm et al. in 2007 also show a tapered cone style feeder to be the most efficient with regard to limiting hay waste when feeding large round bales of alfalfa-grass hay are fed. They compared a tapered cone feeder to unrolling bales on the ground and processing hay into windrows using a PTO-driven bale processor. The tapered cone had 4.3 to 5.0 times less hay waste than that of either rolling out on the ground or using a bale processor (Landbolm et al., 2007). Increased waste in the current trial could be attributed to several components related to feeder design. First the two most efficient feeders (MODC and RING) both have sheeted bottom sections, which aid in containing the hay within the feeder. Secondly, the MODC feeder design positions the bale in the center of the feeder allowing a greater amount of hay to fall into the protected sheeted area while cattle feed. The RING feeder has individual feeding stations which Buskirk et al. reported as being a critical component to reducing hay waste (2003). In their experiment the only feeder without individual feeding stations had three times the amount agonistic interactions and four times as many irregular entrances into the feeder (Buskirk et al, 2003). Hay waste was positively correlated to increased agonistic interactions, frequency of regular and irregular entrances and feeder occupancy rate ($P < 0.05$) (Buskirk et al, 2003).

Table 4.3 shows the effects of feeder and supplement treatment on DMI, as well as DMI as a percentage of cow BW. There were no supplement × feeder treatment interactions on DMI (P =0.97). Supplement had little effect on DMI (P = 0.47). There was a weak trend for DMI to differ among all feeder treatments (P = 0.12). Miller et al., in 2007 reported that cows with ad libitum access to hay consumed 9.4 kg/ cow daily, which is comparable to the results of the current study. Buskirk et al., also reported similar results with regard to DMI (2003). Dry matter intake as a percentage of cow BW was 1.8, 1.8, 2.0 and 1.8 for cows feeding from a cone, ring, trailer, and cradle hay feeder respectively (Buskirk et al, 2003). For this study DMI as a percent of cow BW was 1.70, 1.67, 1.72, and 1.78 % for MODC, OBSR, POLY, and RING respectively.

Performance

The effects of supplementing with monensin on cow performance are shown in Table 4. There were no effects of feeder treatment on performance since all cows in the experiment were exposed to all feeder designs ($P = 0.47$). Also, there were no supplement × feeder treatment interactions so they were removed from the model. There were no effects of supplementation on initial weight, initial BCS, or final weight. The final BCS of cows supplemented with CONT was less than that of cows supplemented with MON ($P = 0.01$). Weight gain, which was calculated as: final weight - initial weight, was greater for cows supplemented with MON ($P = 0.04$). This is concurrent with results from Turner et al. (1977) who reported greater weight gain ($P < 0.05$) in two experiments with cows supplemented with 200 mg MON daily as compared to those that were not. However, Clanton et al., (1981) reported that there were no differences in weight gain in cows supplemented with varying levels of MON ($P > 0.05$). In a 1988 review, Sprott et al. summarized that supplementing MON to gestating beef cows with MON has produced mixed results regarding weight gain and BCS change. Within the current study change in BCS was greater for cows supplemented with MON than those that were not ($P < 0.01$). Daily gain during the 57-d feeding period was also greater for MON supplemented cows than CONT supplemented cows ($P < 0.04$). This is similar to results of Turner et al. (1977) in which cows supplemented with MON achieved an ADG of 0.43 kg/d, compared to 0.23 kg/d for cows supplemented without MON.

Apparent Digestibility

The effects of feeder design and supplementation of beef cows with MON on digestibility is displayed in Table 5. There were no feeder × supplement interactions. Feeder design did not largely affect digestibility ($P > 0.05$). Cows supplemented with MON had greater DM, OM, NDF, and ADF total tract apparent digestibility ($P < 0.05$). There was a tendency for MON supplemented cows to have greater total tract apparent CP digestibility ($P = 0.08$). Comparable research on the effects of supplemental MON on apparent digestibility is limited. Conversely, Dinius et al. found no differences in apparent digestibility of DM, CP, NDF or ADF between steers on a forage diet supplemented with MON ($P > 0.10$) (1976). Similarly in 1981 Muntifering et al. reported no effect of supplementing beef steers on a largely concentrate diet with MON on apparent total tract OM, starch or ruminal, postruminal, or total tract CP digestibility ($P > 0.10$).

Implications

Hay waste was significantly affected by the feeder design used to provide free choice hay to beef cows. The use of a MODC feeder resulted in the least amount of hay waste during the duration of the feeding period, which is similar to earlier work. The difference in hay waste between the MODC and POLY feeders could greatly affect the profitability of a cow/calf operation due to the feeding of less hay with proper feeder design selection. Cow DMI was not restricted by the use of any of the feeder designs and were similar across all treatments. Furthermore, DMI was not affected by diet supplementation with MON. Supplemental MON did result in gains in performance and apparent digestibility when compared to the CONT supplement. However, comparable research yielded mixed results and thus further exploration of the effects of supplemental MON on digestibility and performance in beef cows is needed.

LITERATURE CITED

Bevers, Stan. 2010.Southwest Cow-Calf SPA Key Measures Summary (Long Term Average). Accessed Jan. 21, 2011. http://agrisk.tamu.edu/library/pdf/pdf/SW%20Key%20Measures%20Summary%20_Long%20Term%20Average_.pdf.

Bell, S. and F. A. Martz. 1973. Res. Rep. Univ. of Missouri Agric. Exp. Sta. Columbia, MO.

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.

Dinius, D. A., M. E. Simpson, and P. B. Marsh. 1976. Effect of monensin fed with forage on digestion and the ruminal ecosystem of steers. J. Anim. Sci. 42:229-234.

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

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. 17:295-302.

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.

Muntifering, R. B., B. Theurer, and T. H. Noon. 1981. Effects of monensin on site and extent of whole corn digestion and bacterial protein synthesis in beef steers. J. Anim. Sci. 53:1565-1573.

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.

Turner, H. A., R. J. Raleigh, and D. C. Young. 1977. Effect of monensin on feed efficiency for maintaining gestating mature cows wintered on meadow hay. J. Anim. Sci. 44:338-342.

Vestal, M., W. Clement, D. Doye, D. Lalman. 2007. Cow-calf production practices in Oklahoma Part 1. http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-4570/AGEC-245web.pdf Accessed July 10, 2010.

Table 4.1. Nutrient composition of hay fed (DM basis)

	Feeder[1]					Supplement[2]			P-value[3]	
Item[5], %	OBSR	POLY	RING	MODC	SEM[4]	CONT	MON	SEM[4]	Feeder	Supplement
DM	97.30	97.33	97.34	97.32	0.23	97.28	97.36	0.16	0.99	0.75
Ash	6.21	6.25	6.18	6.09	0.11	6.24	6.13	0.08	0.77	0.35
NDF	66.35	66.44	66.43	65.87	0.24	65.93	66.61	0.17	0.31	0.01
ADF	43.36	43.89	43.62	43.52	0.61	43.29	43.90	0.43	0.94	0.33
ADIA	3.87	3.82	3.57	3.69	0.16	3.87	3.61	0.11	0.55	0.11
CP	5.25	5.44	5.61	5.56	0.11	5.47	5.46	0.08	0.12	0.91

[1] OBSR = conventional open bottom steel ring feeder; POLY = polyethylene pipe ring feeder; RING = sheeted bottom steel ring feeder; MODC = modified cone feeder.
[2] CONT = 36% CP cottonseed meal based pellet with 0 mg/head of monensin; MON = 36% CP cottonseed meal based pellet with 200 mg/head of monensin.
[3] Observed significance levels for main effects.
[4] SEM of the Least squares means.
[5]All values are from laboratory analyses and are presented on a 100% DM basis (except DM).

Table 4.2. Effects of feeder design and supplement on hay waste

	Feeder[1]					Supplement[2]			*P*-value[3]	
Item	OBSR	POLY	RING	MODC	SEM[4]	CONT	MON	SEM[4]	Feeder	Supplement
n	7	7	7	7		14	14			
Dry waste, kg	183.3[a]	206.2[a]	103.1[b]	58.3[b]	26.0	152.7	122.7	21.8	0.02	0.43
Wet waste, kg	54.1[a]	58.3[a]	41.9[a,b]	10.1[b]	12.7	44.7	37.5	8.98	0.12	0.63
Total waste, kg	236.6[a]	265.3[a]	144.3[b]	69.2[b,c]	26.2	197.4	160.3	18.7	< 0.01	0.30
Orts weight, kg	36.53[a]	30.0[a]	45.07[a]	102.9[b]	10.8	62.67	44.57	10.0	0.11	0.33
Waste, % bale wt[5]	20.7[a]	21.49[a]	12.69[b]	5.56[c]	1.56	15.51	14.75	1.81	< 0.01	0.79

[1] OBSR = conventional open bottom steel ring feeder; POLY = polyethylene pipe ring feeder; RING = sheeted bottom steel ring feeder; MODC = modified cone feeder.
[2] CONT = 36% CP cottonseed meal based pellet with 0 mg/head of monensin; MON = 36% CP cottonseed meal based pellet with 200 mg/head of monensin.
[3] Observed significance levels for main effects.
[4] SEM of the Least squares means.
[5] Hay waste expressed as a percentage of mean bale wt.

Table 4.3. Effects of feeder design and supplement on DMI (DM basis)

	Feeder[1]					Supplement[2]			*P*-value[3]	
Item	OBSR	POLY	RING	MODC	SEM[4]	CONT	MON	SEM[4]	Feeder	Supplement
NO.	56	56	56	56		28	28			
DMI, kg/hd/d	8.19	8.43	8.75	8.37	0.24	8.29	8.59	0.28	0.12	0.45
DMI, % BW[5]	1.67	1.72	1.78	1.70	0.05	1.69	1.75	0.06	0.12	0.45

[1] OBSR = conventional open bottom steel ring feeder; POLY = polyethylene pipe ring feeder; RING = sheeted bottom steel ring feeder; MODC = modified cone feeder.
[2] CONT = 36% CP cottonseed meal based pellet with 0 mg/head of monensin; MON = 36% CP cottonseed meal based pellet with 200 mg/head of monensin.
[3] Observed significance levels for main effects.
[4] SEM of the Least squares means.
[5] DMI expressed as a percentage of initial mean BW.

Table 4.4. Effects of supplemental M on cow performance

	Supplement[1]			
Item	CONT	MON	SEM[2]	*P*-value[3]
No.	28	28		
Initial BW, kg	491.8	495.4	9.6	0.79
Initial BCS	5.15	5.21	0.10	0.70
Final BW, kg	507.9	524	10.6	0.28
Final BCS	5.28	5.81	0.14	0.01
Change in BW	16.1	29.61	4.6	0.04
Change in BCS	0.13	0.57	0.12	0.01
ADG, kg/d	0.28	0.51	.08	0.04

[1] CONT = 36% CP cottonseed meal based pellet with 0 mg/head of monensin; MON = 36% CP cottonseed meal based pellet with 200 mg/head of monensin.
[2] SEM of the Least squares means.
[3] Observed significance levels for main effects.

Table 4.5. Effects of feeder design and supplement on apparent digestibility

	Feeder[1]					Supplement[2]			*P*-value[3]	
Item	OBSR	POLY	RING	MODC	SEM[4]	CONT	MON	SEM[4]	Feeder	Supplement
No.	4	4	4	4		2	2			
Apparent Digestibility, %										
DM	56.03	55.64	57.01	54.56	1.98	53.48	58.14	1.41	0.85	0.03
OM	58.68	58.20	59.28	57.00	1.91	56.06	60.52	1.36	.86	0.03
NDF	58.01	57.92	60.18	57.93	1.72	55.70	61.32	1.22	0.74	< 0.01
ADF	47.44	47.08	49.03	45.09	2.48	43.83	50.49	1.76	0.74	0.01
CP	52.46	53.07	55.75	50.56	2.28	50.88	55.04	1.62	0.46	0.08

[1] OBSR = conventional open bottom steel ring feeder; POLY = polyethylene pipe ring feeder; RING = sheeted bottom steel ring feeder; MODC = modified cone feeder.
[2] CONT = 36% CP cottonseed meal based pellet with 0 mg/head of monensin; MON = 36% CP cottonseed meal based pellet with 200 mg/head of monensin.
[3] Observed significance levels for main effects.
[4] SEM of the Least squares means.


(a) (b)


(c) (d)

Figure 4.1. Round bale feeder types: (a) modified cone feeder; MODC, (b), conventional open bottom steel ring feeder; OBSR, (c) polyethylene pipe ring feeder; POLY, and (d) sheeted bottom steel ring feeder; RING.

VITA

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Findings and Conclusions:

Four experiments evaluated the effects of hay processing, bale feeder type and supplementation on hay utilization of beef cattle. Experiment 1used 64 crossbred gestating beef cows with two levels of hay processing (long stemmed [LONG] and pre-cut [PCUT]) and two hay feeders (conventional ring feeder [RING] and cone [CONE]). LONG hay had less waste than PCUT (P = 0.003). CONE feeders wasted less hay than RING feeders (P = 0.0002). DMI was not affected by treatments. The second experiment utilized 96 crossbred, weaned calves in assessing the effect of hay processing on post weaning performance. No practical differences were found (P = 0.65). In the third experiment, cow/calf pairs were used to evaluate the effect of hay type on hay utilization. LONG hay wasted less than PCUT (P = 0.03). DMI was not affected by treatment (P = 0.66). Finally the effects of feeder type and supplemental monensin (MON) on hay utilization in beef cows was evaluated using 56 crossbred beef cows in a split-plot with a completely randomized design with supplement as the main unit and a feeder design as the subunit. The main unit included two supplement treatments, while the subunit included four hay feeder designs. Supplement treatments included a 36% CP cottonseed meal based pellet with 0 (CONT; control) or 200 mg/head of MON, fed at a rate of 1.36 kg/ head daily. Feeder treatments included a conventional open bottomed steel ring (OBSR), a sheeted bottomed steel ring (RING), a polyethylene pipe ring (POLY), and a modified cone feeder (MODC). Hay waste was affected by feeder design (P < 0.01). Supplement did not affect hay waste (P = 0.81). DMI was not affected by supplement (P = 0.45) but trended to differ among feeder types (P = 0.12). Supplemental MON improved cow performance (P < 0.05) and apparent digestibility (P < 0.05). The results of these experiments illustrate the importance of bale feeder design, hay processing, and supplementation on a cow/calf operation's profit potential considering that nutritional costs account for 40 to 60% of the annual budget.

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