NUTRITIONAL AND RANGE MANAGEMENT PRACTICES FOR BREEDING BEEF FEMALES

by

LEOPOLDO ARTURO PACHECO IV

B.S., Texas Tech University, 2004
M.S., Texas Tech University, 2007

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Animal Sciences and Industry
College of Agriculture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2013

Abstract

The objective of this series of studies was to develop and improve methods of production in cow/calf operations of the Great Plains. Ultrasound measures of longissimus muscle depth (**LMD**) and intramuscular fat (**IMF**) of Angus × heifers were used to predict lifetime cow productivity. IMF and LMD were categorized into high, medium, and low groups (**IMFG** and **LMDG**, respectively). Cows in the high and medium LMDG had greater ($P < 0.05$) pregnancy rates than cows in the low LMDG. Calf BW at weaning increased ($P < 0.05$) as dam IMF increased. Angus crossbred cows grazing native range were used to evaluate the effects of pre-partum ruminally-protected choline (**RPC**) supplementation on postpartum beef cow and calf performance. Under the conditions of our study, RPC supplementation had minimal ($P > 0.05$) effects on pregnancy rates and performance of beef cows and calves. Lactating crossbred cows with calves and non-pregnant, non-lactating Boer-cross nannies were used to evaluate the effects of co-grazing on herbivory patterns and animal performance while grazing native tallgrass rangeland infested heavily by sericea lespedeza (**SL**). The proportion of individual SL plants that had been grazed at the end of the trial was greater ($P < 0.01$) in co-grazed pastures than in single-species pastures. Grazing cows and goats in combination increased ($P < 0.01$) grazing pressure on SL without negatively affecting beef cow performance, beef calf performance, or residual forage biomass. Angus × cows and heifers grazing native range were used to evaluate the effects of pre-partum corn steep liquor supplementation on postpartum beef cow and calf performance. Under the conditions of our study, CSL supplementation did not generally promote beef cow and calf performance that was equivalent to supplementation with an isonitrogenous, dry, corn-soy alternative. Cow calf pairs were used to evaluate the effects of grazing system (**GS**) and stocking rate (**SR**) on cow and calf performance. Late season rest-rotation (**LSRR**) was compared with continuous (**CONT**) grazing at low, moderate, and high SR. Under the conditions of our study, CONT produced consistently better ($P < 0.01$) late-season cow and calf performance than LSRR. Season-long effects of SR on animal performance were minimal; moreover, GS and SR treatments produced equivalent pregnancy rates.

NUTRITIONAL AND RANGE MANAGEMENT PRACTICES FOR BREEDING BEEF FEMALES

by

LEOPOLDO ARTURO PACHECO IV

B.S., Texas Tech University, 2004
M.S., Texas Tech University, 2007

A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Animal Sciences and Industry
College of Agriculture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2013

Approved by:

Major Professor
KC Olson

Abstract

The objective of this series of studies was to develop and improve methods of production in cow/calf operations of the Great Plains. Ultrasound measures of longissimus muscle depth (**LMD**) and intramuscular fat (**IMF**) of Angus × heifers were used to predict lifetime cow productivity. IMF and LMD were categorized into high, medium, and low groups (**IMFG** and **LMDG**, respectively). Cows in the high and medium LMDG had greater (P < 0.05) pregnancy rates than cows in the low LMDG. Calf BW at weaning increased (P < 0.05) as dam IMF increased. Angus crossbred cows grazing native range were used to evaluate the effects of pre-partum ruminally-protected choline (**RPC**) supplementation on postpartum beef cow and calf performance. Under the conditions of our study, RPC supplementation had minimal (P > 0.05) effects on pregnancy rates and performance of beef cows and calves. Lactating crossbred cows with calves and non-pregnant, non-lactating Boer-cross nannies were used to evaluate the effects of co-grazing on herbivory patterns and animal performance while grazing native tallgrass rangeland infested heavily by sericea lespedeza (**SL**). The proportion of individual SL plants that had been grazed at the end of the trial was greater (P < 0.01) in co-grazed pastures than in single-species pastures. Grazing cows and goats in combination increased (P < 0.01) grazing pressure on SL without negatively affecting beef cow performance, beef calf performance, or residual forage biomass. Angus × cows and heifers grazing native range were used to evaluate the effects of pre-partum corn steep liquor supplementation on postpartum beef cow and calf performance. Under the conditions of our study, CSL supplementation did not generally promote beef cow and calf performance that was equivalent to supplementation with an isonitrogenous, dry, corn-soy alternative. Cow calf pairs were used to evaluate the effects of grazing system (**GS**) and stocking rate (**SR**) on cow and calf performance. Late season rest-rotation (**LSRR**) was compared with continuous (**CONT**) grazing at low, moderate, and high SR. Under the conditions of our study, CONT produced consistently better (P < 0.01) late-season cow and calf performance than LSRR. Season-long effects of SR on animal performance were minimal; moreover, GS and SR treatments produced equivalent pregnancy rates.

Table of Contents

List of Figures

List of Tables

Acknowledgements

The time I have spent in the Flint Hills has been a life-changing experience. I have learned a lot from my professors and friends at Kansas State University. The knowledge which I have gained during my time at KSU has opened many doors for me and will continue to lead me to many great opportunities. My time here has also helped me define what I want to do with my life as a professional.

I would like to first thank Dr. KC Olson. The wealth of knowledge gained from my time under your guidance is invaluable. My family and I would not have the opportunities that are ahead of us without you. I would also like to thank my committee members, Dr. John Jaeger, Dr. Dale Blasi and Dr. Dan Thompson. I am truly honored you all supported me and allowed me to experience a Ph. D program under such great direction.

Another group of people who have made my time at KSU a truly memorable experience would be my fellow graduate students. I especially want to thank Eric Bailey and Garret Preedy. My time as an R.A. would have been extremely difficult at times without these men. When I couldn't depend on anyone else they were always willing to saddle up in the best and worst of weather to get the job done.

Finally and most importantly I would like to thank my family for their love and support. My wife Wrenn has supported me and allowed me to follow my dreams. I truly appreciate her patience and willingness to allow me to continue my education. I am a blessed man to have her in my life and I cannot wait to start the next chapter of our lives raising kids and cattle. To my parents, Juana and Ross and L.A. and Janet, thanks for instilling in me the value of an education.

Chapter 1 - A Review of Literature

Relationship between ultrasonically-measured beef cow carcass traits and lifetime productivity

Ultrasound in the Beef Industry

Ultrasound has become widely-used in the beef industry to predict carcass merit in live animals and to assess the value of individuals as breeding stock. Ultrasound has many advantages over carcass evaluation including: it is relatively inexpensive, it produces results that can be analyzed in real time, and it is a non-terminal procedure. Furthermore, data obtained with ultrasound is subject to less selection bias than that which is collected through sire progeny-testing programs. Ultrasound measures of fat thickness (**FT**),longissimus-muscle area, (**LE**; Perkins et al., 1992; Herring et al., 1994; Bergen et al., 1996),and intramuscular fat percentage (**IMF**; Reverter et al., 2000; Hassen et al., 2001) are accurate predictors of their corresponding carcass traits in fed slaughter cattle. Thus, average heritability estimates of ultrasound measures of FT, LE, and IMF for breeding beef cattle are moderate to high. This moderate-to-high heritability promotes confidence that selecting seedstock animals based on ultrasound characteristics will improve carcass characteristics of their progeny.

Ultrasound and its Impact on Seedstock Production

Live-animal ultrasound (**US**) measurements of sire carcass characteristics and the subsequent relationships to progeny carcass characteristics has been widely investigated. Research conducted by Moser et al. (1998), Devitt and Wilton, (2001), and Reverter et al. (2000) reported that there were positive genetic correlations between US measurements of sire carcass characteristics and the corresponding carcass measurements of fed cattle.

Sapp et al. (2002) conducted a study to determine the impact of selecting sires based on phenotypic yearling ultrasound intramuscular fat percentage (**UIMF**) on marbling scores of steer progeny. Prior to this research, little information was available regarding the consequences of sire selection based on US measures and the relationships between sire UIMF and marbling scores of their progeny. In the study, yearling Angus bulls were selected for high-phenotypic UIMF (i.e., UIMF - EPD), or for low phenotypic UIMF-EPD. It was found that high UIMF-EPD sires produced steer progeny with significantly greater marbling and USDA quality grade when compared to sires with low UIMF-EPD. They determined that by using UIMF, co-selection for increased marbling and acceptable external fat thickness was much more rapid than using conventional carcass evaluation. Using US in this way could accelerate genetic progress in seedstock and slaughter cattle alike.

Devitt and Wilton (2001) drew much the same conclusion: genetic evaluations for carcass traits based on US measurements of yearling cattle have the potential to increase the rate of genetic progress and reduce the expense involved in progeny testing. Their research evaluated genetic correlation estimates between US measurements of yearling-bull carcass traits and carcass measurements of finished steer progeny. Devitt and Wilton (2001) reported that age-constant heritability measurements for LMA, UIMF, US 12th-rib backfat, and average daily post-weaning gain were 0.48, 0.23, 0.52, and 0.46, respectively. Similarly strong heritability estimates were reported for other weight-constant traits in the same study. Furthermore, there were also age-constant genetic correlation estimates between steer-carcass LMA and sire-ultrasound LMA, steer carcass 12th-rib backfat and sire US 12th-rib backfat, steer carcass marbling and sire US intramuscular fat, and steer ADG and sire ADG measured as 0.66, 0.88, 0.80, and 0.72, respectively. These researchers concluded there were strong, positive genetic correlation estimates between sire US measurements and corresponding steer carcass measurements. They suggested that genetic improvement for steer carcass traits could be achieved by using yearling bull US measurements as selection criteria. They further suggested that yearling US measurements of carcass traits could be used under the assumption that genetic differences detected with US at yearling age would be reflected in carcasses of finished progeny.

Determining the Appropriate Time to Evaluate Seedstock Ultrasonically

Hassen et al. (2003) noted genetic and residual variance components for US measures in young, breeding beef cattle needed to be determined for a wide range of ages and production conditions. They estimated variance components, heritability, and repeatability of serially-measured US data in purebred Angus bulls and heifers. Hassen et al. (2003) reported that heritability and repeatability of US-predicted carcass measurements in young Angus cattle were optimally collected between 52 and 63 wk of age. This study proposed the now-standard practice of collecting US measures of yearling bulls and of 13- to 14-mo-old heifers to evaluate the genetic potential of future generations of Angus seedstock. The authors concluded that a large proportion of the phenotypic variance in US measurements collected at ages < 13 mo was not genetic but environmental; selection based on US at < 13 mo may be counter-productive.

Conclusion

The work of Moser et al. (1998), Devitt and Wilton (2001), Reverter et al. (2000),and Sapp et al. (2002) were interpreted to suggest that selecting seedstock based on US measures of IMF, RE and FT were reliable selection criteria as a means of improving carcass characteristics of future progeny. In addition, selection based on US appeared to have significant advantages in terms of speed and repeatability over selection based on terminal carcass evaluation. Unfortunately, much of the literature focuses on sire selection and the impact ultrasound has on improving carcass traits in future generations. Ultrasound measurements of beef females have been used in much the same way as in sire selection (i.e., aimed at improving carcass quality in future progeny); however, no existing work has evaluated the use of US measurements to identify and predict critical production-related characteristics of beef cows.

Effects of pre-partum rumen-protected choline supplementation on performance of beef cows and calves

The Biological Role of Choline

Choline is classified as an essential nutrient. Most animals synthesize choline *de novo* but it must also be consumed in the diet because synthesis is inadequate to meet a relatively-large biological demand. Choline is most commonly found in specialized fat molecules known as phospholipids and is required for their formation. Choline is also a component of lectithin, acetylcholine, certain plasmalogens, and sphingomyelins of nervous tissue. In the latter role, choline is critical for normal brain function, neuromuscular signaling, and nerve transmission. In addition, choline serves as a methyl donor for the synthesis of carnitine; carnitine is essential for fatty acid oxidation.

In non-ruminants, choline deficiency is rarely exhibited because choline is widely distributed in plant and animal tissues. Conversely, Sharma and Erdman (1989) reported that dietary choline was rapidly degraded in the rumen and little post-ruminal flow of choline was detectable in ruminants. Erdman and Sharma (1991) subsequently conducted an *in vitro* study using a lipid-encapsulated choline source (i.e., ruminally-protected choline; RPC) and found that 87% of the supplied choline escaped ruminal degradation. Zahra et al. (2006), Suksombat et al. (2011), and Pinotti et al. (2003) reported that supplementing RPC to lactating dairy cows increased milk production by supplying choline post-ruminally. This research was interpreted to suggest that supplementing RPC increased the amount of choline available for metabolic processes, which in turn had positive effects on maternal performance.

Dietary Needs of Choline by Cattle

In ruminants, one of the primary roles of choline is in the formation of phosphatidylcholine, which is a primary constituent of cell membranes. Phosphatidylcholine is also required for production of very low density lipoprotein (**VLDL**) by the liver. In times of high energy demand, cattle mobilize large amounts of fatty acids from adipose tissue. This, in turn, increases concentrations of non-esterified fatty acids (**NEFA**) in the bloodstream. Generally, NEFA can be used directly by most tissues as a source of energy but most is processed hepatically. In the liver, NEFA are esterified to triglycerides, oxidized to ketone bodies, or oxidized to carbon dioxide. The esterification of NEFA to triglycerides and their export to adipose depot sites via VLDL involves choline. Hepatic capacity for NEFA incorporation into VLDL is relatively low in ruminants (Morrow, 1976). If excessive uptake of NEFA by the liver occurs, fatty liver disease may develop. It is possible that increased availability of phosphatidylcholine may allow greater transport of NEFA away from the liver via augmentation of VLDL supply (Cooke et al., 2007).

Dairy cattle most often experience fatty-liver disease during the periparturient period and during early lactation, as described by Piepenbrink and Overton (2003), Suksombat et al. (2011), and Janovick-Guretzky et al. (2006). Pinotti et al. (2003) reported that supplementing RPC during the periparturient period improved fat processing in the liver of over-conditioned dairy cows by providing additional choline for synthesis of phosphatidylcholine, which subsequently allowed for greater export of triglycerides from the liver via VLDL. Piepenbrink and Overton (2003) reported that supplementing RPC decreased the capacity of the liver to accumulate NEFA, thus reducing the incidence of fatty liver in over-conditioned dairy cows.

Use of RPC in Beef Cows

While fatty liver disease can occur in beef cows, it is not common because they typically do not have access to the nutrient-dense diets that are characteristic of lactating dairy cattle. Jaeger et al. (2008) suggested reproductive benefits of RPC may result from more efficient use of NEFA by supplemented cows. Although these authors indicated that hepatic lipid metabolism may have been more efficient for RPC-supplemented cows than untreated cows, there were no differences in BW or BCS change between supplemented and unsupplemented cows in their study.

Conclusions

The reports of Pinotti et al. (2003) and Piepenbrink and Overton (2003) were interpreted to suggest that feeding RPC to over-conditioned dairy cows from the periparturient period through early lactation improved hepatic lipid metabolism. Improved lipid metabolism occurred through provision of additional choline for synthesis of phosphatidylcholine and, subsequently, through increased export of triglycerides from the liver via VLDL. Improved lipid metabolism in dairy cows fed RPC was associated also with increased milk production (Zahra et al., 2006; Suksombat et al., 2011; Pinotti et al., 2003). While the benefits of supplementing dairy-cow diets with RPC seem reasonably clear, pre-partum supplementation of beef cows with RPC and associated effects on reproductive efficiency are not well understood and warrant further investigation.

Effects of co-grazing on herbivory patterns and performance by cattle and goats grazing native tallgrass rangeland infested by sericea lespedeza (Lespedeza cuneata)

Sericea Lespedeza

Sericea lespedeza (*Lespedeza cuneata;* SL) is a highly-fecund, grazing-resistant noxious weed (USDA, 2010). In managed rangelands, SL spreads quickly and profoundly damages wildlife habitat and livestock forage resources.

Sericea lespedeza is a perennial legume of herbaceous to woody growth form that was first introduced into the United States in the 1890s from Asia. Early land managers recognized that lespedeza was adaptable, tolerant of shallow, acidic or low-fertility soils, and resistant to insects and disease. This combination of traits made SL a widely-used plant for reseeding strip-mined lands, highway right-of-ways, dams, and waterways in the US for nearly a century.

Regrettably, SL is a highly competitive and prolific seed producer, and individual plants are capable of producing 481 to 950 kg of seed / ha each year (Vermeire et al., 2007). Vigorous seed production allows SL to rapidly infiltrate native grasslands that are adjacent to reseeding projects. In addition, seed can be transported great distances via the alimentary canal and hair of wild and domestic herbivores. In Kansas alone, SL has infested ~2,530 km^2 of pasture, primarily in the Flint Hills region, reducing native grass production by up to 92% through a combination of aggressive reproduction, canopy dominance, and allelopathy (Kalburtji and Mosjidis 1992; Dudley and Fick 2003; Eddy and Obermeyer 2003). The resulting damage to native habitats for wildlife and pasture quality for domestic herbivores has been devastating.

Herbicides retard the spread of SL but application is difficult and expensive under the best of circumstances and impossible in steep or rocky terrain (Eddy and Obermeyer 2003); moreover, herbicides are lethal to ecologically-important, non-target plant species. Increased grazing pressure on SL by domestic herbivores may slow its spread and facilitate some measure of biological control. Unfortunately, mature plants contain high levels of condensed tannins which reduce protein digestion by beef cattle and are a strong deterrent to grazing (Jones and Mangan 1977; Eckerle et al., 2010, 2011a-c). Negligible grazing pressure by most classes of wild and domestic herbivores results in low rates of intake for SL in native and managed grassland ecosystems.

The predominant grazing management practice in the Flint Hills of eastern Kansas involves annual spring burning in March or April followed by intensive grazing with yearling beef cattle for a relatively short period from April to August (Owensby et al., 2008). During seasonal grazing, 40 to 60% of annual graminoid production is removed and grazing lands then remain idle for the remainder of the year. Under this prevailing management practice, invasion by SL into the tallgrass prairie biome has steadily increased (Eddy et al., 2003). Sericea lespedeza flowers and produces seed in late summer from August to September (Cope and Burns 1974, Eckerle et al., 2010). The absence of grazing pressure, prescribed burning, and other means of biological control during late summer strongly promote seed production, seed distribution, and continued invasion of the Flint Hills ecoregion by this noxious weed.

Anti-quality Factors that Inhibit Grazing of Sericea Lespedeza

Sericea lespedeza has relatively high levels of protein prior to reproductive maturity (12 to 16% CP); it also has high levels of condensed tannins (CT; Eckerle et al., 2010). Makkar (2003) reported that CT decreased growth, decreased feed intake, decreased digestive enzyme activity, and decreased *in vivo* protein utilization. Condensed tannins bind with dietary protein in the gut and render them unavailable to ruminal microbes (Jones and Mangan, 1977; Eckerle et al., 2011a, 2011b, and 2011c). Tannin levels in SL increase with maturity and under drought conditions, thus the plant is only palatable to most classes of ruminants while the plant is young and tannin levels are low (Preedy et al., 2013). Waghorn (2008) indicated that ruminants consuming high-tannin forages like SL experienced a build-up of tannin-protein complexes in the rumen that suppressed forage DMI substantially and caused a general digestive upset. Ruminants quickly recognized the discomfort associated with consuming plants with high levels of CT and developed an aversion to them (Eckerle et al., 2011a). Peak CT concentration in SL occurs during budding, flowering, and seed formation. Herbivory is discouraged under these circumstances (Preedy et al., 2013), which effectively promotes maximal seed production by individual SL plants.

Ruminant Adaptation to High-CT Diets

Waghorn (2008) suggested certain browsing ruminants may have salivary characteristics which enable them to be more tolerant of high-CT diets than ruminants that are primarily roughage consumers. Tannins are known to interact strongly with proline-rich proteins; early researchers in the field hypothesized that the saliva of browsers contained high concentrations of proline-rich proteins when compared to other grazing herbivores (Mole et al., 1990; Fickel et al., 1998). Conversely, Makkar (2003) reported that proline-rich proteins were not plentiful in the saliva of domestic ruminants like cattle, sheep and goats; therefore, alternative explanations were sought.

Browsers have a greater proportion of parotid salivary tissue in relation to BW than other classes of ruminants (Vaithiyanathan et al., 2001). Lamy et al. (2010) fed sheep and goats diets with divergent CT levels and investigated changes in parotid saliva volume and composition. They reported an increase in volume of parotid saliva secretion and an increase in parotid salivary protein concentrations as sheep and goats were transitioned from a control, low-CT diet to a diet high in CT. They concluded that even though sheep and goats may not produce high levels of proline-rich proteins in parotid saliva, they appeared able to adapt to high-CT diets by producing parotid saliva in greater volume and with greater protein concentrations. This unique characteristic of browsers led to their extensive use in management of high-CT shrubs around the world.

Utilizing Goats to Control Invasive Plants

Goats are increasingly used for controlling invasive weeds and woody plants on rangelands. While goats require specialized fencing, parasite control, and predator control, they have proven a valuable resource for improving deteriorated rangelands. A growing body of research has reported that goats can be a cost effective means of selectively removing vegetation that is unpalatable or toxic to beef cattle, including leafy spurge (*Euphorbia esula L.*), post oak (*Quercus stellata*), blackjack oak (*Quercus marilandica*), and SL. Lacey et al. (1992) and Walker et al. (1994) reported that goats effectively removed leafy spurge from rangelands in the northwestern United States. Blackjack oak and post oak were reduced on native rangelands in Texas and Oklahoma when goats were used to graze these woody browse species (Darrow and McCully, 1959. In the Flint Hills of Kansas, juvenile goats suppressed SL growth and seed production when stocked at a rate of approximately 10 goats / ha during a 4-mo summer grazing season (Hart, 2000).

Conclusions

The spread of SL and its negative effects on cattle performance and native rangelands is well understood by producers in Kansas. Sadly, intervention is often times not implemented until infestations are severe, resulting in the need for costly eradication methods involving chemical application and mechanical mowing. Hart (2000) reported that goats were an effective, sustainable, and profit-generating means of removing SL and improving rangeland condition. Hart (2001) later remarked that the most significant factor to be overcome with using goats to control SL is the bias with which cattle producers in the Kansas Flint Hills tend to regard goat husbandry. Investigations of grazing systems that incorporate goats with traditional beef cattle production may be necessary to overcome this bias and demonstrate the effectiveness of goat herbivory in SL control.

Effects of pre-partum corn steep liquor supplementation on performance of beef cows and calves

Protein Supplementation for Grazing Beef Cows

Intake of mature, dormant forages is often limited due to low CP content (< 7%; Mathis and Sawyer, 2007). This reduction in forage intake is due to the lack of peptides, amino acids and ammonia which are products of protein degradation in the rumen. Structural carbohydrate-fermenting ruminal microbes depend particularly on ammonia that is produced ruminally via the fermentation of ruminally-degradable protein (**RDP**) to support their maintenance and proliferation (Olson et al., 1999). By supplying a protein supplement that contains sufficient RDP, intake of low-quality forages by beef cattle increases dramatically, primarily by stimulating rate and extent of DM digestion (Köster et al., 1996). Passage rate also increases in response to supplemental protein and, subsequently, DM intake improves. Choosing a protein supplement that maximizes performance of beef cattle fed low-quality forages requires caution as protein supplements contain varying levels of ruminally-undegradable protein (**RUP**) and RDP.

Use of RUP Supplements

Supplementation with protein sources high in RUP can potentially meet the nitrogen requirements of cattle grazing low-quality forages because of the ruminant's ability to recycle nitrogen in the form of urea from the liver to the rumen via the bloodstream. Anderson et al. (2001) evaluated the effects of RDP or RUP supplements on performance of postpartum first-calf heifers with *ad libitum* access to low-quality grass hay in two 60-d experiments. In experiment 1, 4 treatments were tested: 1) deficient in RDP and metabolizable protein (**MP**), 2) deficient in RDP but adequate in MP, 3) adequate in RDP but deficient in MP, and 4) adequate in RDP and MP. Supplements were fed daily. In experiment 1, heifers receiving adequate supplemental RDP, regardless of MP status, had improved BW and BCS gain as well as improved nitrogen digestibility. Forage intake, milk production, calf weight, digestibility of OM, and digestibility of ADF were unaffected by treatments. In experiment 2, the same treatments used in experiment 1 were evaluated on a 3-day/week supplement delivery schedule. In contrast to experiment 1, cows that were supplemented with adequate MP, regardless of RDP status, had increased weight gain relative to other treatments but BCS was unaffected by treatment. Calves whose dams were supplemented adequate RDP had greater ADG and BW than calves whose dams were supplemented MP. The authors interpreted the data to suggest that RDP and RUP were both adequate protein sources for beef cows consuming low-quality forage.

Alderton et al. (2000) supplied primiparous beef cows with an RDP supplement, an RDP + RUP supplement, or an RUP supplement for 120 d postpartum and evaluated the effect of treatments on cow and calf performance. Forage intake was similar among treatments. Cows supplemented RDP + RUP had greater milk production at 30 d postpartum than RUP-supplemented cows; RDP-supplemented cows were intermediate in milk production. In contrast, RDP + RUP- and RDP-supplemented cows had similar levels of milk production 60 d postpartum. However, both had greater milk production than RUP-supplemented cows 60 d postpartum. Supplementation with RDP + RUP resulted in greater BCS at 60, 90, and 120 d postpartum than other treatments, whereas cows supplemented with RDP alone had greater BCS than RUP-supplemented cows on d 60 postpartum. Postpartum interval to first estrus, conception rates, and calf performance were unaffected by treatments. The authors interpreted the data to suggest that supplying supplemental RUP in addition to or in replacement of RDP had minimal effects on the performance of primiparous beef cows consuming low quality forage.

Bailey et al. (2011) evaluated the effects of supplying three levels of RUP to pre-partum beef cows in a two-part experiment. In both experiments, cows were supplemented RDP at 0.09% BW with increasing levels of RUP: 0.05% BW (**LOW**), 0.07% BW (**MOD**), or 0.09% BW (**HI**). In experiment 1, cows were offered low-quality prairie hay ad libitum. Intake and digestion were monitored between weeks 14 and 4 pre-partum. Forage DMI, total DMI, and total DM digestibility were greater for cows supplemented LOW than for cows fed MOD or HI supplements. In experiment 2, cows were offered the same supplements but grazed dormant native tallgrass pastures. Cow ADG, BCS change, pregnancy rate, and calving interval were unaffected by treatments. The authors suggested that supplementing RDP at 0.09% of BW supplied sufficient MP to maximize performance under the conditions of their study and that changing supplementation programs in order to supply more RUP was not warranted.

Use of RDP Supplements

Supplying protein to cattle grazing low-quality forage improves performance (Clanton and Zimmerman, 1970; Pruitt et al., 1993; Beaty et al., 1994). Furthermore, RDP is thought to be the first-limiting nutrient to cattle consuming low-quality forages. Mathis et al. (2000) evaluated the effects of supplying RDP to beef steers on utilization of medium- to low-quality forages. In the 3-part study, ruminally-cannulated steers were offered medium- to low-quality forages along with supplemental RDP at 0, 0.041, 0.082, or 0.124% BW. Forages included bermudagrass (8.2% CP, 71% NDF; Exp. 1), smooth bromegrass (5.9% CP, 65% NDF; Exp. 2), and forage sorghum (4.3% CP, 60% NDF; Exp. 3). In experiment 1, forage OM intake (**FOMI**) and fiber digestion were not influenced by increasing levels of RDP supplementation. The authors suggested that the forage provided in Exp 1 had sufficient levels of RDP (8.2% of total digestible OM intake; **TDOMI**) to support adequate intake and DM digestibility levels. In experiment 2, supplemental RDP did not affect FOMI but total OM intake (**TOMI**) tended to increase with increasing levels of RDP supplementation, resulting in a tendency toward linear increase in TDOMI. The greatest magnitude of improvement in TDOMI was observed in the group supplemented RDP at 0.082% BW. In experiment 3, FOMI, TOMI, OM digestion, and TDOMI were improved by increasing levels of RDP supplementation. The authors interpreted the data to suggest that supplying supplemental RDP to steers improved intake and digestion of low-quality forages but indicated that the magnitude of improvement in intake and digestion was variable and dependent on forage type.

Köster et al. (1996) examined the effect of increasing RDP supplementation on intake and digestion of low-quality tallgrass prairie forage by beef cows. In the study, RDP was supplemented to ruminally- and duodenally-cannulated cows with *ad libitum* access to low-quality tallgrass prairie hay (1.9% CP, 77% NDF). Cows were supplemented RDP at rates of 0, 180, 360, 540 or 720 g/d. Forage OM intake increased with increasing supplemental RDP, peaking at 540 g/d of supplemental RDP. Ruminal OM and NDF digestion increased with the addition of 180 g/d of supplemental RDP. In contrast, increases in OM and NDF digestion were moderate and variable at greater levels of supplementation of RDP. Microbial N flow and efficiency increased with increasing levels of RDP supplementation. Total duodenal N flow responded quadratically, reaching maximum at 540 g/d of supplemental RDP. Total ruminal volatile fatty acids and ammonia concentrations increased with RDP supplementation. The authors suggested that providing supplemental RDP to cattle maintained on low-quality forage would result in improved forage intake and digestibility. Furthermore, they recommended that to maximize intake and digestion of low-quality forages a total of 11% of TDN should be supplied as RDP.

The ruminally-degradable protein requirements of gestating beef cows grazing native Sandhills range during winter were evaluated by Hollingsworth-Jenkins et al. (1996) in a 2-part study. In experiment 1, beef cows were supplemented RDP at 50%, 75%, 100% or 125% of estimated requirements during the last half of gestation. In experiment 2, supplemental RDP levels were 29%, 65%, 100% or 139% of estimated requirements. In trial 1, daily gain and change in BCS between treatments were not different between treatments. In trial 2, daily gain responded quadratically, with cows supplemented RDP at 65% of predicted requirements experiencing greater gains than cows receiving RDP at 29%, 100% and 139% of predicted RDP requirements. Likewise, BCS change responded similarly with cows supplemented at the 65% level maintaining body condition and the remaining treatments losing condition over the duration of the supplementation period. In both trials, forage DM intake was similar amongst treatments. In trial 1, forage OM digestibility increased linearly in response to increasing levels of RDP supplementation. In trial 2, OM digestibility was not affected by treatment. The authors deduced that the RDP requirements of beef cows grazing dormant Sandhills range fell between 340 and 430 g/d which was estimated to be 4% of OM intake or 7.1% of digestible OM. Therefore, gestating beef cows grazing in these conditions would require supplementation of between 61.7 and 140 g/d of RDP daily; moreover, the level of RDP supplementation would also be dependent on forage quality, intake, and cow BW.

Use of Corn Milling Co-products as Supplements for Grazing Cattle

Corn milling co-products have characteristics that make them well-suited for supplementation of low-quality forage diets. Both wet- and dry-milling processes remove all or most of the starch in corn grain, eliminating negative associative effects on fiber digestion which can occur when energy is supplemented in the form of starch. Olson et al. (1999) found that supplementing starch to cattle fed low-quality forages depressed forage DM intake. This decrease in forage intake was thought to be due to competitive effects between starch- and fiber-fermenting bacteria. Corn co-products can be an excellent source of supplemental protein and have the additional benefit of supplying supplemental energy in the form of highly-digestible fiber. Corn co-products with high relative DM proportions are generally used more often in commercial livestock production because they are easier to handle with traditional feeding equipment than competing low-DM products. In spite of that, liquid co-products have characteristics that make them suitable for low-quality forage supplementation programs when acceptable storage and handling facilities are in place. Corn steep liquor (**CSL**), a byproduct of the wet-corn milling process, is a good source of protein, free amino acids, energy, vitamins, and minerals for beef cattle (Wagner et al., 1983). Corn steep liquor is approximately 50% DM and 35% CP on a DM basis (Stalker et al., 2010). Wagner et al. (1983) evaluated the use of CSL, condensed molasses solubles (**CMS**), and fermented ammoniated condensed whey (**FACW**) as protein sources for beef cows grazing dormant native range. Cows supplemented with CSL lost less BW and body condition than cows supplemented CMS and FACW. Cows supplemented with CSL performed similarly to cows that were supplemented with soybean meal or cottonseed meal. Additionally, CSL-supplemented cows had increased ruminal ammonia concentrations and lower ruminal pH than cows supplemented with CMS and FACW. The authors concluded that CSL was an acceptable protein supplement for beef cows grazing dormant native range.

Conclusions

Mathis and Sawyer (2007) reported that forage intake of dormant, low-quality range forages can be limited due to low CP intake. Supplying protein to cattle grazing low-quality forages improves performance (Clanton and Zimmerman, 1970; Pruitt et al., 1993; Beaty et al., 1994). Feedstuffs with relatively large proportions of ruminally-undegradable protein have been considered the preferred source of supplemental protein for beef cows grazing low-quality forage; however, Anderson et al. (2001), Alderton et al. (2000) and Bailey et al. (2011) reported varying results on the effectiveness of RUP as a supplement. Ruminally-degradable protein improved forage intake and performance of beef cows consuming low-quality forage as shown by the work of Bailey et al. (2011), Mathis et al. (2000), Köster et al. (1996), and Hollingsworth-Jenkins et al. (1996). Wagner et al. (1983) reported that corn steep liquor was useful as a source of supplemental RDP for cattle grazing low-quality forage. Furthermore, with a large supply of corn milling co-products available to much of the U.S. cow-calf industry, investigation of the effectiveness of these products as supplements for low-quality forages is warranted.

Literature Cited

Alderton, B. W., D. L. Hixon, B. W. Hess, L. F. Woodard, D. M. Hallford, and G. E. Moss. 2000. Effects of supplemental protein type on productivity of primiparous beef cows. J. Anim. Sci. 78:3027-3035.

Anderson, L. P., J. A. Paterson, R. P. Ansotegui, M. Cecava, and W. Schmutz. 2001. The effects of degradable and undegradable intake protein on performance of lactating first-calf heifers. J. Anim. Sci. 79:2224-2232.

Bailey, E. A., E. C. Titgemeyer, R. C. Cochran, T. J. Jones, and K. C. Olson. 2011. Influence of ruminally-undegradable protein supplementation and advancing gestation on forage use and performance by beef cows consuming low-quality, warm season forage. Proc. West. Sec. Amer. Soc. Anim. Sci. 62:217-221.

Beaty, J. L., R. C. Cochran, B. A. Lintzenich, E. S. Vanzant, J. L. Morrill, R. T. Brandt, Jr., and D. E. Johnson. 1994. Effect of frequency of supplementation and protein concentration in supplements on performance and digestion characteristics of beef cattle consuming low-quality forages. J. Anim. Sci. 72:2475-2486.

Bergen, R. D., J. J. McKinnon, D. A. Christensen, and N. Kohle. 1996. Prediction of lean yield in yearling bulls using real-time ultrasound. Can. J. Anim. Sci. 76:305-311.

Clanton, D. C., and D. R. Zimmerman. 1970. Symposium on pasture methods for maximum production of beef cattle: protein and energy requirements for female beef cattle. J. Anim. Sci. 30:122.

Cooke, R. F., N. Silva Del Rio, D. Z. Caraviello, S. J. Bertics, M. H. Ramos, and R. R. Grummer. 2007. Supplemental choline for prevention and alleviation of fatty liver in dairy cattle. J. Dairy Sci. 90:2412-2418.

Cope, W.A., and J.C. Burns. 1974. Components of forage quality in sericea lespedeza in relationship to strain, season, and cutting treatments. Agron. J. 66:389-394.

Darrow, F. A., and W. G. McCully. 1959. Brush control and range improvement in the post oak-blackjack oak-area of Texas. Texas Agric. Exp. Sta. Bull. 942.

Devitt, C.J.B., and J. W. Wilton. 2001. Genetic correlation estimates between ultrasound measurements on yearling bulls and carcass measurements on finished steers. J. Anim. Sci. 79:2790-2797.

Dudley, D. M., and W. H. Fick. 2003. Effects of sericea lespedeza residues on selected tallgrass prairie grasses. Trans. Kansas Acad. Sci. 106:166-170.

Eckerle, G. J., K. C. Olson, J. R. Jaeger, J. L. Davidson, T. K. Kraft, and L. A. Pacheco. 2010. Effects of sun-curing and harvest maturity on concentration and protein-binding capacity of condensed tannins in sericea lespedeza (*Lespedeza cuneata*). Proc. West. Sec. Amer. Soc. Anim. Sci. 61:30-34.

Eckerle, G. J., K. C. Olson, J. R. Jaeger, J. W. Waggoner, J. L. Davidson, and L. A. Pacheco. 2011a. High-tannin forage utilization by beef cows I. intake and digestion of tallgrass prairie hay contaminated with sericea lespedeza (*Lespedeza cuneata*). Proc. West. Sec. Amer. Soc. Anim. Sci. 62:199-202.

Eckerle, G. J., K. C. Olson, J. R. Jaeger, J. W. Waggoner, J. L. Davidson, and L. A. Pacheco. 2011b. High-tannin forage utilization by beef cows II. effects of corn steep liquor (CSL) supplementation on intake and digestion of tallgrass prairie hay contaminated with sericea lespedeza (*Lespedeza cuneata*). Proc. West. Sec. Amer. Soc. Anim. Sci. 62:203-206.

Eckerle, G. J., K. C. Olson, J. R. Jaeger, J. W. Waggoner, J. L. Davidson, and L. A. Pacheco. 2011c. High-tannin forage utilization by beef cows III. effects of corn steep liquor supplementation on voluntary selection of tallgrass prairie hay contaminated with sericea lespedeza (*Lespedeza cuneata*) and uncontaminated tallgrass prairie hay. Proc. West. Sec. Amer. Soc. Anim. Sci. 62:207-210.

Eddy, T., J. Davidson, and B. Obermeyer. 2003. Invasion dynamics and biological control prospects for sericea lespedeza in Kansas. Great Plains Research: A Journal of Natural and Social Sciences. 13:217-230.

Erdman, R. A., and B. K. Sharma. 1991. Effect of dietary rumen-protected choline in lactating dairy cows. J. Dairy Sci. 74:1641-1647.

Fickel, J., F. Goritz, B. A. Joest, T. Hildebrant, R. R. Hofmann, and G. Breves. 1998. Analysis of parotid and mixed saliva in roe deer (*Capreolus capreolus L.*). J. Comp. Physiol. 168:257-264

Hart, S. P. 2000. Stocker goats for controlling sericea lespedeza. Pp. 12-13 *in* Symp. Proc. Sericea Lespedeza and the Future of Invasive Species. Kansas State University, Department of Agronomy, Manhattan Kansas.

Hart, S. P. 2001. Recent perspectives in using goats for vegetation management in the USA. J. Dairy Sci. 84(E Suppl.):E170-E176.

Hassen, A., D. E. Wilson, and G. H. Rouse. 2003. Estimation of genetic parameters for ultrasound-predicted percentage of intramuscular fat in Angus cattle using random regression models. J. Anim. Sci. 81:35-45.

Hassen, A., D. E. Wilson, V. R. Amin, G. H. Rouse, and C. L. Hays. 2001. Predicting percentage of intramuscular fat using two types of real-time ultrasound equipment. J. Anim. Sci. 79:11-18.

Herring, W. O., D. C. Miller, J. K. Bertrand, and L. L. Benyshek. 1994. Evaluation of machine, technician, and interpreter effects on ultrasonic measures of backfat and longissimus muscle area in beef cattle. J. Anim. Sci. 72:2216-2226.

Hollingsworth-Jenkins, K. J., T. J. Klopfenstein, D. C. Adams, and J. B. Lamb. 1996. Ruminally-degradable protein requirement of gestating beef cows grazing native winter Sandhills range. J. Anim. Sci. 74:1343-1348.

Jaeger, J. R., S. R. Goodall, K. R. Harmoney, and K. C. Olson. 2008. Beef cow performance following rumen-protected choline supplementation during the periparturient period. Proc. West. Sec. Amer. Soc. Anim. Sci. 59:114-117.

Janovick-Guretzky, N. A., D. B. Carlson, J. E. Garrett, and J. K. Drackley. 2006. Lipid metabolite profiles and milk production for Holstein and Jersey cows fed rumen-protected choline during the periparturient period. J. Dairy Sci. 89:188-200.

Jones, W. T., and J. L. Mangan. 1977. Complexes of the condensed tannins of sainfoin (*Onobrychis viciifolia* Scop.) with fraction 1 leaf protein and with submaxillary mucoprotein, and their reversal by polyethylene glycol and pH. J. Sci. Food Agric. 28:126-136.

Kalburtji, K. L., and J. A. Mosjidis. 1992. Effects of sericea lespedeza residues on warm-season grasses. J. Range. Manage. 45:441-444.

Köster, H. H., R. C. Cochran, E. C. Titgemeyer, E. S. Vanzant, I. Abdelgadir, and G. St-Jean. 1996. Effects of increasing degradable intake protein on intake and digestion of low-quality, tallgrass-prairie forage by beef cows. J. Anim. Sci. 74:2473-2481.

Lacey, J. R., R. Wallander, and K. Olson-Rutz. 1992. Recovery, germinability, and viability of leafy spurge (*Euphorbia esula*) seeds ingested by sheep and goats. Weed Technol. 6:566-602.

Lamy, E., G. da Costa, R. Santos, F. Capela e Silva, J. Potes, A. Pereira, A. V. Coelho, and E. Sales Baptista. 2010. Effect of condensed-tannin ingestion on sheep and goat parotid saliva proteome. J. Anim. Physiol. Anim. Nutr. (Berl.) 95:304-312.

Makkar, H. P. 2003. Effects and fate of tannins in ruminant animals, adaptation to tannins, and strategies to overcome detrimental effects of feeding tannin-rich feeds. Small Rum. Res. 49: 241-256.

Mathis, C. P., and J. E. Sawyer. 2007. Nutritional management of grazing beef cows. Vet. Clin. Food Anim. 23:1-19.

Mathis, C. P., R. C. Cochran, J. S. Heldt, B. C. Woods, I. E. Abdelgadir, K. C. Olson, E. C. Titgemeyer, and E. S. Vanzant. 2000. Effects of supplemental degradable intake protein on utilization of medium- to low-quality forages. J. Anim. Sci. 78:224-232.

Mole, S., L. G. Butler, and G. Iason. 1990. Defense against dietary tannin in herbivores: a survey for proline rich salivary proteins in mammals. Biochem. System. Ecol. 18:287-293

Morrow, D. A. 1976.Fat cow syndrome. J. Dairy Sci. 59:1625-1629.

Moser, D. W., J. K. Bertrand, I. Misztal, L. A. Kriese, and L. L. Benyshek. 1998. Genetic parameter estimates for carcass and yearling ultrasound measurements in Brangus cattle. J. Anim. Sci. 76:2542-2548.

Olson, K. C., R. C. Cochran, T. J. Jones, E. S. Vanzant, E. C. Titgemeyer, and D. E. Johnson. 1999. Effects of ruminal administration of supplemental degradable intake protein and starch on utilization of low-quality, warm-season grass hay by beef steers. J. Anim. Sci. 77:1016-1025.

Owensby, C.E., L. M. Auen, H. F. Berns, and K. C. Dhuyvetter. 2008. Grazing systems for yearling cattle on tallgrass prairie. Range. Ecol. and Manage. 61:204-210.

Perkins, T. L., R. D. Green, and K. E. Hamlin. 1992. Evaluation of ultrasonic estimates of carcass fat thickness and longissimus-muscle area in beef cattle. J. Anim. Sci. 70:1002-1010.

Piepenbrink, M. S., and T. R. Overton. 2003. Liver metabolism and production of cows fed increasing amounts of rumen-protected choline during the periparturient period. J. Dairy Sci. 86:1722-1733.

Pinotti, L., A. Baldi, I. Politis, R. Rebucci, L. Sangalli, and V. Dell'Orto. 2003. Rumen-protected choline administration to transition cows: effects on milk production and vitamin E status. J. Vet. Med. Assoc. 50:18-21.

Preedy, G. W., L. W. Murray, W. H. Fick, L. A. Pacheco, E. A. Bailey, D. L. Davis, A. V. Siverson, and K. C. Olson. 2013. High-tannin forage utilization by beef cows V. Effects of corn steep liquor supplementation on dietary botanical composition of beef cows grazing native range infested by sericea lespedeza (*Lespedeza cuneata*). Proc. West. Sec. Amer. Soc. Anim. Sci.64:317-325.

Pruitt, R. J., M. C. Namminga, R. H. Haigh, and D. B. Young. 1993. Level of available forage and supplemental protein and energy for cows grazing winter range. SDSU Beef Report MP 93:4-7.

Reverter, A., D. J. Johnston, H. U. Graser, M. L. Wolcott, and W. H. Upton. 2000. Genetic analyses of live-animal ultrasound and abattoir carcass traits in Australian Angus and Hereford cattle. J. Anim. Sci. 78:1786-1795.

Sapp, R. L., J. K. Bertrand, T. D. Pringle and D. E. Wilson. 2002. Effects of selection for ultrasound intramuscular fat percentage in Angus bulls on carcass traits of progeny. J. Anim. Sci. 80:2017-2022.

Sharma, B. K., and R. A. Erdman. 1989. In vitro degradation of choline from selected feedstuffs and choline supplements. J. Dairy Sci. 72:2772-2776.

Stalker, A., R. Rasby, G. Erickson, C. Buckner, and T. Klopfenstein. 2010. Feeding corn milling co-products to forage-fed cattle.1st ed. Nebraska Corn Board and University of Nebraska, Lincoln, NE.

Suksombat, R., R. Mirattanaphrai, and P. Paengsai. 2011. Performance of lactating dairy cows in response to supplementation of rumen-protected choline. J. Anim. Vet. Adv. 10(24):3321-3327.

USDA. 2010. *Lespedeza cuneata* (Dum. Cours.) distribution in the United States. In: PLANTS profile. Available at: http://plants.usda.gov/java/profile?symbol=LECU. Accessed 02/15/2013.

Vaithiyanathan, S., J. P. Mishra, Q. Sheikh, R. Kumar. 2001. Salivary gland tannin-binding proteins of sheep and goats. Indian J. Anim. Sci. 71:1131-1134.

Vermeire, L. T., T. G. Bidwell, and J. Stritzke. 2007. Ecology and Management of Sericea Lespedeza. Okla. Coop. Ext. PSS-2874. Available at: http://dasnr22.dasnr22.dasnr.okstate.edu/ docushare/dsweb/Get/Rendition-759/PSS-2874web%20color.pdf. Accessed 04/05/12.

Waghorn, G. 2008. Beneficial and detrimental effects of dietary condensed tannins for sustainable sheep and goat production: progress and challenges. Anim. Feed Sci. Technol. 147:116-139.

Wagner, J. J., K. S. Lusby, and G. W. Horn. 1983. Condensed molasses solubles, corn steep liquor ,and fermented ammoniated condensed whey as protein sources for beef cattle grazing dormant native range. J. Anim. Sci. 57:542-552.

Walker, J. W., S. L. Kronberg, S. L. Al-Rowaily, and N. E. West. 1994. Comparison of sheep and goat preference for leafy spurge. J. Range Manage. 47:429-434.

Webb, D. M. 2008. Assessing the potential of mixed grazing goats with beef cattle to improve animal performance and increase the utilization of marginal pastureland in Appalachian coal region. M. S. Thesis. Virginia Polytechnic Institute and State University.

Zahra, L. C., T. F. Duffield, K. E. Leslie, T. R. Overton, D. Putnam, and S. J. LeBlanc. 2006. Effects of rumen-protected choline and monensin on milk production and metabolism of periparturient dairy cows. J. Dairy Sci. 89:4808-4818.

Chapter 2 - **Relationship between ultrasonically-measured beef cow carcass traits and lifetime productivity**

L. A. Pacheco, J. R. Jaeger, J. Minick-Bormann, and K. C. Olson

Abstract

Intramuscular fat (**IMF**) and longissimus muscle depth (**LMD**) are commonly used in the beef industry to aid in replacement heifer selection. The objective of our study was to determine if ultrasonically-measured IMF and LMD were related to lifetime cow productivity and progeny performance. Angus x heifers (n = 160) were managed as a contemporary group and developed in a drylot until breeding at 14 mo of age. Heifer IMF and LMD were measured ultrasonically at 13 mo of age. Each year, females were mass-mated following estrous synchronization and exposed to bulls 10 d later for the remainder of a 45 d breeding season. Heifers were managed in a spring-calving, native range-based production system with a 12-mo calving interval for the duration of the 4 yr study (2004-2007). Animals were examined for pregnancy yearly in August and non-pregnant females were removed from the herd. Cow IMF and LMD were categorized into high, medium, and low groups (< 3.88%, 3.88 to 5.33%, and > 5.33%, respectively, for IMF; < 43.80 mm, 43.80 to 52.02 mm, and > 52.02 mm, respectively, for LMD). Cow IMF, LMD, IMF group (**IMFG**), and LMD group (**LMDG**) were analyzed using a fixed, general, linear statistical model. Pregnancy rate was not related to cow IMF, LMD, or IMFG ($P > 0.05$); however, more cows in the high and medium LMDG were pregnant than cows in the low LMDG ($P < 0.04$). Calving interval and calf BW at birth were not influenced by cow IMF, LMD, IMFG, or LMDG ($P > 0.05$). Calf BW at weaning was not related to dam LMD, IMFG, or LMDG ($P > 0.05$); however, calf BW at weaning increased as dam IMF increased ($P < 0.05$). These data were interpreted to suggest that greater cow IMF was associated with greater progeny BW at weaning. In contrast, cow IMF and IMFG were not related to pregnancy rate, calf BW at birth, or calving interval. Cows with LMD ≥ 43.8 cm were more likely to be pregnant than cows with LMD < 43.8 cm. Further analyses of IMF and LMD and their effects on cow productivity and progeny performance appear warranted as

relationships between simple ultrasound carcass measurements of yearling beef heifers and certain measures of progeny performance appear strong.

Key Words: beef cows, intramuscular fat, longissimus muscle area

Introduction

Ultrasound is widely used in seedstock production, commercial operations, and in feedyards to predict carcass merit. It has also been used to assess the value of individuals as parents in the seedstock industry. Ultrasound has many advantages as a technique to evaluate body composition: it is relatively inexpensive; it produces results more rapidly than progeny testing programs; and data are less prone to selection bias than direct carcass data collection. Ultrasound measures of longissimus muscle area (**LMA**; Perkins et al., 1992; Herring et al., 1994) and proportion of intramuscular fat (**IMF**; Reverter et al., 2000;Hassen et al., 2001) are accurate predictors of their corresponding carcass traits in fed slaughter cattle. Thus, average heritability estimates of ultrasonically-measured REA and IMF are moderate to high. Moderate-to-high heritability allows seedstock producers to select replacement animals with confidence based on ultrasound measurements.

A large body of research has evaluated the use of sire ultrasound measures as a predictor of progeny carcass measurements and growth. In contrast, little research has examined the use of ultrasonically-measured compositional traits as a means to predict cow productivity and subsequent progeny performance. Available data in this area appear to be limited to terminal carcass evaluation. Davis and coworkers (1983) concluded that replacement-heifer carcass traits, measured at 240 d of age, were not associated with efficiency of subsequent progeny; they suggested that identification of heifers that will produce offspring with superior efficiency may prove difficult using terminal carcass evaluation.

The objective of our experiment was to examine the relationship between ultrasound measures of IMF and longissimus muscle depth (**LMD**) collected on heifers at yearling age and long-term measurements of cow productivity and progeny performance. Specifically, we wished to determine whether ultrasound measurements of IMF and LMD obtained from yearling heifers were related to measurements of calf birth weight, calf weaning weight, cow pregnancy rate, and calving interval collected later in life.

Materials and Methods

Animals and Data Collection

Angus-cross heifers (n = 160) were obtained from the KSU Agricultural Research Center-Hays herd or purchased from 2 sources with similar genetics and breeding seasons were managed as a contemporary group. All procedures used in the care, handling, and sampling of animals in our study were approved by the Kansas State University Institutional Animal Care and Use Committee (protocol no. 2650). Females were developed in a drylot and had *ad libitum* access to a grower diet (Table 2.1) and clean water. At 13 mo of age, measurements of heifer IMF and LMD at the 12th to 13th-rib interface were obtained. Ultrasound images were generated using an Aloka 500V (Aloka Co., Ltd, Wallingford, CT) B-mode instrument equipped with a 3.5-MHz general-purpose transducer array (UST 5021-125 mm window). Images were collected by a single technician using software from the Cattle Performance Enhancement Company (CPEC, Oakley, KS). Twelfth-rib fat thickness, LMD, and IMF were estimated with procedures that incorporated image analysis software (Brethour, 1994) integral to the CPEC product. Marbling scores were coded such that 4.0 = slight^{00} (low select) and 5.0 = small^{00} (low choice). Measurements of IMF and LMD were categorized into low, medium, and high groups (< 3.88%, n = 26; 3.88 to 5.33%, n = 107; and > 5.33%, n = 27; respectively, for IMF and < 43.80 mm, n = 21; 43.80 to 52.02 mm, n = 116; and > 52.02 mm, n = 23; respectively, for LMD). Following breeding at approximately 14 mo of age, heifers were managed in a spring-calving, native range-based production system with a 12-mo calving interval for the duration of the 4 yr study (2004-2007). Each year, females were mass-mated following estrous synchronization and exposed to Angus bulls 10 d later for the duration of a 45-d breeding season. Pregnancy rate to AI was determined 31 to 35 d after fixed-time AI with transrectal ultrasonography. Cows were examined for pregnancy in August each year via rectal palpation and non-pregnant females were removed from the herd. Calves were weighed individually at birth and at weaning. Weaning weights were adjusted to a constant 205 d of age, for age of dam, and for sex of calf using the equation (Beef Improvement Federation, Guidelines 9th edition; 2010):

$$ADJ\ 205d\ wt = \left(\left(\frac{Weaningwt - Birthwt}{Daysofage}\right) \times 205\right) + Birthwt + Sexadjustment + Damadjustment$$

Statistics

All data were analyzed using the MIXED and LOGISTIC procedures of SAS (SAS Inst. Inc., Cary, NC). The mixed model included fixed effects of year, calf sex, IMF group (**IMFG**), and LMD group (**LMDG**) on calf birth BW, calf weaning BW, and calving interval. The logistic model included fixed effects of year, calf sex, IMFG, and LMDG on pregnancy rate. When protected by a significant F-test ($P \leq 0.05$), least-squares treatment means were separated using the method of Least Significant Difference. Least-squares treatment means were considered different when $P \leq 0.05$.

Results and Discussion

Pregnancy rate was not related to cow IMF, LMD, or IMFG ($P > 0.05$); however, more cows became pregnant in the high and medium LMDG compared to the low LMDG ($P < 0.04$; Table 2.2); therefore, light muscling may be associated with lesser fertility. Calving interval was not related to cow IMF, LMD, IMFG, or LMDG ($P > 0.05$; Tables 2.2 & 2.3).

Calf BW at birth was not related to dam IMF, LMD, IMFG, or LMDG ($P > 0.05$; Tables 2.2 & 2.3). Calf 205-d adjusted weaning BW was not related to dam LMD, IMFG, or LMDG ($P >$

0.05); however, calf 205-d adjusted weaning BW increased as dam IMF increased ($P < 0.05$). These data were interpreted to suggest that heifer IMF was associated with greater progeny BW at weaning. Based on these data, each 1% increase in IMF was associated with a 3.9 kg increase in calf BW at weaning.

Greater heifer IMF at weaning may be related to greater growth efficiency by progeny. Change in cow weight:height from calving to weaning was positively related to calf growth efficiency (Davis et al., 1983; Davis et al., 1985). Conversely, several studies have reported negative relationships between dam weight gain or weight:height and pre-weaning ADG and F:G of progeny (Gregory et al., 1950; Brinks et al., 1962; Todd et al., 1968; Kress et al., 1969; Carpenter et al., 1972; Hohenboken et al., 1973).

Cow IMF was not related to pregnancy rate, calf BW at birth, or calving interval; moreover, cow LMD and IMFG were not related to pregnancy rate, calf BW at birth, calf 205-d adjusted weaning BW, or calving interval. Calf 205-d adjusted weaning BW increased numerically as LMDG and IMFG increased. Hohenboken and colleagues (1973) reported that there were small positive correlations between cow size at parturition and calf size at birth and weaning. Cow size at parturition would be due, in part, to heaviness of muscling; therefore, LMD should be related to BW at weaning. Arnold and coworkers (1991) concluded that when ultrasonically-measured LE was adjusted to a constant age, there was a positive genetic correlation to 205-d adjusted weaning BW of progeny. Use of ultrasound for longissimus-muscle area measurement provided a potential rate of change of 0.32 cm^2/yr, which was nearly 2-fold greater than when testing 10 progeny / sire (0.17 cm^2/yr) via terminal carcass measurements.

Implications

Further analyses of IMF and LMD and their effects on cow productivity and progeny performance appear warranted as relationships between simple US carcass measurements of yearling beef heifers and certain measures of progeny performance appear strong.

Tables

Table 2.1. Diet fed to replacement heifers from weaning to 14 mo of age

Item	**DM, %**
Ingredient composition	
Ground sorghum hay	82.5
Ground sorghum grain	9.42
Soybean meal	7.07
Vitamin/mineral premix	0.52
Calcium carbonate	0.26
Salt	0.26
Nutrient analysis	
DM, %	79.4
CP, %	10.7
NE_m, Mcal/lb	0.67
NE_g, Mcal/lb	0.34
NDF, %	47.4
ADF, %	35.3
TDN, %	60.6
Calcium, %	0.86
Phosphorus, %	0.21
Sulfur, %	0.17

Table 2.2. Relationship between longissimus muscle depth (LMD) in heifers at 13 mo of age and production measures collected from 2 to 5 yr of age

	Longissimus muscle depth group*		
	Low	**Medium**	**High**
Trait (mean ± S.E.)	**(< 43.80 mm)**	**(43.80–52.02 mm)**	**(> 52.02 mm)**
Calf BW at birth, kg	37.2 ± 1.0	35.9 ± 0.3	35.6 ± 0.7
Calf 205-d adjusted weaning BW, kg	232.8 ± 6.6	239.0 ± 4.4	243.0 ± 5.7
Calving interval, d	350.6 ± 5.1	343.6 ± 4.0	345.6 ± 4.9
Pregnancy rate, %	78.0[a]	91.0[b]	88.0[b]

* Longissimus muscle depth (LMD) was measured at 13 mo of age with ultrasound and heifers were categorized into high, medium or low LMD groups.

[a,b] Within a row, means without a common superscript differ (*P* < 0.05).

Table 2.3. Relationship between intramuscular fat group (IMFG) in heifers at 13 mo of age and production measures collected from 2 to 5 yr of age

	Intramuscular fat group*		
	Low	**Medium**	**High**
Trait (mean ± S.E.)	**(< 3.88%)**	**(3.88–5.33%)**	**(> 5.33%)**
Calf BW at birth, kg	36.0 ± 0.7	37.0 ± 0.3	36.1 ± 0.7
Calf 205-d adjusted weaning BW, kg	235.9 ± 5.3[a]	239.3 ± 4.5[b]	244.1 ± 5.8[c]
Calving interval, d	344.0 ± 4.7	345.8 ± 4.2	342.4 ± 4.7
Pregnancy rate, %	92.7	89.4	84.9

* Intramuscular fat (IMF) was measured at 13 mo of age with ultrasound and heifers were categorized into high, medium or low IMF groups.

[a,b,c] Within a row, means without a common superscript differ ($P < 0.05$).

Literature Cited

Arnold, J. W., J. K. Bertrand, L. L. Benyshek, and C. Ludwig. 1991. Estimates of genetic parameters for live animal ultrasound, actual carcass data, and growth traits in beef cattle. J. Anim. Sci. 69:985-992.

Brethour, J. R. 1994. Estimating marbling score in live cattle from ultrasound images using pattern recognition and neural network procedures. J. Anim. Sci. 72:1425-1432.

Brinks, J. S., R. T. Clark, N. M. Kieffer, and J. R. Quesenberry. 1962. Mature weight in range Hereford cows – heritability, repeatability and relationship to calf performance. J. Anim. Sci. 21:501-504.

Carpenter, J. A., Jr., H. A. Fitzhugh, Jr., T. C. Cartwright, and R. C. Thomas. 1972. Relationships between calf performance and mature size of beef cows. Texas Agric. Exp. Sta. Prog. Rep. 3118.Texas A&M Univ., College Station. Pp 27–30.

Davis, M. E., J. J. Rutledge, L. V. Cundiff, and E. R. Hauser. 1983. Life cycle efficiency of beef production. II. relationship of cow efficiency ratios to traits of the dam and progeny weaned. J. Anim. Sci.57:852-866.

Davis, M. E., J. J. Rutledge, L. V. Cundiff, and E. R. Hauser. 1985. Life cycle efficiency of beef production. VI. relationship of cow efficiency ratios for progeny slaughtered to growth, condition, fertility, and milk production of the dam. J. Anim. Sci. 60:69-80.

Gregory, M. E., C. T. Blunn, and M. L. Baker. 1950. A study of some factors influencing the birth and weaning weights of beef calves. J. Anim. Sci. 9:338-346.

Hassen, A., D. E. Wilson, V. R. Amin, G. H. Rouse, and C. L. Hays. 2001. Predicting percentage of intramuscular fat using two types of real-time ultrasound equipment. J. Anim. Sci. 79:11-18.

Herring, W. O., D. C. Miller, J. K. Bertrand, and L. L. Benyshek. 1994. Evaluation of machine, technician, and interpreter effects on ultrasonic measures of backfat and longissimus muscle area in beef cattle. J. Anim. Sci. 72:2216-2226.

Hohenboken, W. D., E. R. Hauser, A. B. Chapman, and L. V. Cundiff. 1973. Phenotypic correlations between dam traits expressed during development and lactation and traits of progeny in cattle. J. Anim. Sci. 37:1-10.

Kress, D. D., E. R. Hauser, and A. B. Chapman. 1969. Efficiency of production and cow size in beef cattle. J. Anim. Sci. 29:373-383.

Perkins, T. L., R. D. Green, and K. E. Hamlin. 1992. Evaluation of ultrasonic estimates of carcass fat thickness and longissimus muscle area in beef cattle. J. Anim. Sci. 70:1002-1010.

Reverter, A., D. J. Johnston, H. U. Graser, M. L. Wolcott, and W. H. Upton. 2000. Genetic analyses of live-animal ultrasound and abattoir carcass traits in Australian Angus and Hereford cattle**.** J. Anim. Sci. 78:1786-1795.

Todd, J. C., J. K. Riggs, and J. C. Smith. 1968. Milk yields and calf weights from Brahman, Hereford and crossbred cows in the Gulf Coast Prairie. J. Anim. Sci. 27(Suppl.1):286.

Chapter 3 - **Effects of pre-partum, ruminally-protected choline supplementation on performance of beef cows and calves**

L. A. Pacheco, J. R. Jaeger, L. R. Hibbard, M. J. Macek, N. A. Sproul, G. J. Eckerle, E. A. Bailey, and K. C. Olson

Abstract

Three trials were conducted to evaluate the effects of pre-partum, ruminally-protected choline supplementation on postpartum beef cow and calf performance. Angus x cows (Trial 1: n = 181, initial BW 653 ± 6.6 kg; Trial 2: n = 144, initial BW 606 ± 6.0 kg, Trial 3: n = 438, initial BW 532 ± 5.9 kg) grazing native range were blocked by BW and parity and assigned randomly to 1 of 2 treatments: a grain-soy supplement (**CON**) or a grain-soy supplement + ruminally-protected choline (**RPC**). Treatments were applied 50 (Trial 1), 40 (Trial 2) and 60 d (Trial 3) prior to earliest predicted calving date. In each experiment, cows were fed 2.38 kg of CON or RPC 6 × per week. The feeding rate of choline averaged 4.5 g/cow daily. Body weight, BCS, and ultrasonically-measured longissimus muscle characteristics (intra-muscular fat, IMF; longissimus muscle depth, **LDM**) of cows and BW of calves were recorded at intervals from January to October. In trial 1, cow BW, BW change, BCS and BCS change were not different ($P \geq 0.17$) between treatments. Cow 12th-rib backfat thickness (**BF**) and BF change were not different ($P \geq 0.29$) between RPC- and CON-supplemented cows. Cow LMD was not different ($P \geq 0.11$) between treatments on d 0, d 50, at calving, or on d 146, relative to the onset of the trial. Conversely, LMD was greater (P = 0.04) for RPC supplemented cows than CON supplemented cows on d 120. Cows supplemented with CON had a more favorable change in LMD (P = 0.04) than RPC-supplemented cows from d 0 to d 146. Cow IMF on d 0, d 50, at calving, and on d 146 and cow IMF change from d 0 to d 146 were not different ($P \geq 0.10$) between RPC- and CON-supplemented cows. In contrast, CON-supplemented cows had greater (P = 0.01) IMF scores than RPC supplemented cows on d 120. The proportion of cows that conceived to fixed-time AI tended to be greater (P = 0.11) for RPC-supplemented cows than CON-supplemented cows; however, final pregnancy rate was not different (P = 0.49) between CON and RPC. Supplementation with RPC had no effect ($P \geq 0.71$) on calf BW at birth, on d 146, and on d 256. Conversely, calves from CON-supplemented cows

tended (*P* = 0.07) to have greater ADG from birth to d 146 than calves from RPC-supplemented cows. Calf ADG from d 146 to d 256, calf ADG from birth to d 256, and adjusted 205-d BW were not different ($P \geq 0.23$). In trial 2, cow BW, BW change, BCS and BCS change during supplementation were not affected ($P \geq 0.20$) by treatment. Treatment did not affect ($P \geq 0.18$) change in BF, IMF, or LMD. Calf BW at birth and at d 250 were not different ($P \geq 0.25$) between treatment groups. In addition, calf ADG from birth to weaning and adjusted 205-d BW were not different ($P \geq 0.71$) between treatments. Conception to fixed-time AI tended (*P* = 0.13) to be greater for RPC than for CON but final pregnancy rate was not different (*P* = 0.46) between CON and RPC. In trial 3, cow BW and BCS were not different ($P \geq 0.30$) between treatments at d 0 and at d 60, relative to the onset of the study. Cow BF, LMD and IMF were not different ($P \geq 0.35$) amongst treatments at d 0 or at the end of the supplementation period (d 60). Cow BF change and cow IMF change from d 0 to d 60 were not different ($P \geq 0.39$) between treatments. Conversely, LMD change from d 0 to d 60 tended to be (*P* = 0.10) greater for CON-supplemented cows than for RPC supplemented cows. At calving, RPC cows were heavier (*P* = 0.01) than CON cows; however, cow BCS at calving was unaffected by treatment (*P* = 0.53). Cow BW and BCS were not different ($P \geq 0.13$) at d 125, d 190 and d 250, relative to the onset of the study, between treatments. Cow BW change and cow BCS change from d 0 to d 250 were not different ($P \geq 0.24$) by treatment. Timed-AI and overall pregnancy rates were also not different ($P \geq 0.33$) between treatments. Calf ADG during the first portion of the summer grazing season (birth to 08/01) was not different ($P \geq 0.14$) between treatments; however, calf ADG from 08/01 to weaning tended to be greater (*P* = 0.09) for calves of RPC-supplemented cows than for calves of CON-supplemented cows. In contrast, adjusted 205-d calf BW and birth-to-weaning ADG were not affected ($P \geq 0.51$) by dam treatment. Under the conditions of our studies, pre-partum RPC supplementation had minimal effects on performance of beef cows and calves. It does not appear that further work in this area is warranted.

Key Words: beef cows, choline, supplementation

Introduction

Pre-partum nutrient supplementation of spring-calving beef cows is a vital part of cow/calf enterprises, often affecting subsequent reproductive success. Pre-partum dietary supplements vary in nutrient content, depending on the goals of individual production systems. They tend to be nutrient-specific, targeting delivery of macro-nutrients like carbohydrates, fats, or protein. Each of these nutrient-specific supplementation schemes can be employed effectively, provided they are supported properly from a managerial perspective.

Conversely, little focus has been applied to the use of micronutrients in pre-partum beef cow supplements; moreover, there is little information available evaluating the effectiveness of micronutrients in cattle supplements. One such macronutrient is choline. Choline is classified as a B vitamin and an essential nutrient. It is found in many commonly-encountered feedstuffs and forages but is highly degraded during passage through the rumen. This circumstance prevents intestinal absorption of choline in its biologically-active form; therefore, in order to increase post-ruminal absorption, dietary choline must be fed in a manner that allows it to bypass ruminal fermentation. This can be achieved by encapsulating choline in lipid.

Choline and products derived from choline serve a number of critical biological functions. Specifically, phosphatidylcholine and other choline-containing lipids help maintain the structural integrity of animal-cell membranes. Choline-containing phospholipids are also important precursors for intra-cellular messenger and extra-cellular, cell-signaling molecules. Choline is also important for nerve-impulse transmission, as it is a precursor to acetylcholine.

Lipid transport and metabolism are also dependent on choline. Fats consumed in the diet are transported to the liver via chylomicrons. In the liver, fats are esterified and packaged into very low density lipoproteins (**VLDL**), which are then transported through the blood to adipose-depot sites in the body. Phosphatidylcholine is a component of VLDL. Supplementing ruminally-protected choline to beef cows pre-partum could allow for more efficient fat metabolism in the liver during periods of nutritional stress (i.e., parturition and early lactation). Therefore, the objective of our study was to evaluate the effects of pre-partum, ruminally-protected choline supplementation on productivity of the beef cow and, subsequently, productivity of the calf.

Materials and Methods

Animals, Treatments, and Diets

All animal-care and handling procedures were approved by the Kansas State Animal Care and Use Committee (protocol no. 2650).

Trial 1.Angus × cows (n = 181; initial BW 653 ± 6.3kg) at the Western Kansas Agricultural Research Center - Hays were stratified by age, BW, and BCS (1 = emaciated, 9 = obese; Wagner et al., 1988) and assigned randomly to 1 of 2 pre-partum supplementation treatments: control (**CON**) or ruminally-protected choline (**RPC**; Table 3.1). Treatments were initiated 50 d before the first expected calving date and continued for 120 d. During the treatment period, cows were maintained in discrete treatment groups during the pre-partum period and received forage sorghum hay *ad libitum* and 0.95 kg supplement / cow daily. Supplements for RPC-treated cows contained ruminally-protected choline (4 g choline / cow daily) and trace-mineral supplement (Quali-Tech, Chaska, MN); supplements for CON-treated cows were identical in every respect, except that RPC was omitted (Table 3.1).

Trial2. Angus × cows (n = 144; initial BW 606 ± 6.0 kg) at the Western Kansas Agricultural Research Center - Hays were stratified by age, BW, and BCS and assigned randomly to 1 of 2 pre-partum supplementation treatment groups: control (**CON**) or ruminally-protected choline (**RPC**; Table 3.1). Supplementation began 40 d before the first predicted calving date and was halted on the first predicted calving date. Cows were maintained in discrete treatment groups during the pre-partum period and received *ad libitum* forage sorghum hay and 0.95 kg supplement / cow daily. Supplements for RPC-treated cows contained ruminally-protected choline (4 g choline / cow daily) and trace-mineral supplement (Quali-Tech, Chaska, MN); supplements for CON-treated cows were identical in every respect, except that RPC was omitted.

Trial 3. Angus × cows and heifers (n = 438; initial BW 532 ± 6.0 kg) were stratified by age, BCS, and expected calving date and assigned randomly to 1 of 2 treatment groups: 1) a 40% CP mixture of corn and soybean meal + ruminally-protected choline (**RPC**) or 2) a 40% CP mixture of corn and soybean meal (**CON**; Table 3.2). Cows and heifers were managed in two locations: 190 cows and 43 heifers at the Kansas State University Commercial Cow-Calf Unit, Manhattan and 149 cows and 56 heifers at the Western Kansas Agricultural Research Center - Hays. Treatments were applied during a 60 d period that immediately preceded the earliest predicted calving date; each cow was fed 2.38 kg/hd of CON or RPC 6 × per wk. The feeding rate of choline averaged 4.5 g / cow daily. Mature cows and heifers were evenly distributed by treatment, BCS, and expected calving date into 4 native, warm-season pastures at each research location. Cattle were gathered from their pastures at 0700 and sorted into pens by treatment and feed their allotted amount of supplement. Supplement consumption was complete within 1 h at each feeding episode. Supplementation continued until each cow reached parturition. Following parturition, cows were fed CON in their respective pastures until May 15.

Data Collection

*Trial 1.*Cow BW was measured and BCS were assigned on d 0 (supplementation initiation), on d 50, on the d of calving, on d 120 (end of supplementation), and on d 146 (beginning of ovulation synchronization). Backfat thickness at the 12th rib (**BF**), intra-muscular fat percentage

(**IMF**), and 12th-rib longissimus muscle depth (**LMD**) were measured ultrasonically on d 0, d 50, on the d of calving, on d 120, and on d 146 using an Aloka 500V (Aloka Co., Ltd, Wallingford, CT) B-mode instrument equipped with a 3.5-MHz general-purpose transducer array (UST 5021-125 mm window). Images were collected with Cattle Performance Enhancement Company software (CPEC, Oakley, KS). Estimation of BF, LMD, and IMF was executed using procedures integral to the CPEC image-analysis software (Brethour, 1994). Scores related to IMF were coded such that 4.0 = slight^{00} (low select) and 5.0 = small^{00} (low choice). In addition, Calf BW was measured on the day of birth, on d 146 (beginning of dam ovulation synchronization), and on d 256 (weaning).

Trial 2. Cow BW, BCS, and ultrasound measurements were collected at d 0 (supplementation initiation) and d 80 (40 d after supplementation terminated). Backfat thickness, IMF, and LMD were measured in the region of the 12th and 13th ribs via ultrasound using procedures described for Trial 1. Cow BCS was recorded at start of supplementation (d 0) and at calving. Calf BW was recorded at birth and on d 250 (weaning).

*Trial 3.*Cow BW, BCS, and ultrasound measurements were collected at d 0 (supplementation initiation) and d 60 (the end of the supplementation period). Backfat thickness, LMD, and IMF were measured between the 12th and 13th rib interface via ultrasound using procedures described for Trial 1. Cow BW and BCS were also measured at calving, on d 125 (beginning of ovulation synchronization), on d 190 (d of AI-pregnancy determination), and on d 250 (d of weaning). Calf BW were also measured at these times.

Estrous Synchronization and Breeding

In trials 1, 2 and 3 blood samples were collected from all cows the last week of May (21 d prior to timed AI) ; BW and BCS were measured at that time. A second blood sample was collected the second week of June (10 d prior to timed AI), at which time ovulation synchronization was initiated using the CO-Synch + CIDR protocol. A controlled internal drug-releasing insert (CIDR; Pfizer Animal Health, New York, NY) was inserted intravaginally and 100 μg of GnRH (2 mL Ovacyst; IVX Animal Health, St. Joseph, MO) was administered intramuscularly. The CIDR was removed 7 d later and cows were injected intramuscularly with 25 mg of PGF2α (Prostamate, IVX Animal Health, St. Joseph, MO). Fixed-time AI (**TAI**) was initiated, 60 to 64 hours after the PGF2α injection. Cows were inseminated by 1 of 4 technicians using semen from 1 of 6 AI sires. All AI sires were equally represented in each treatment.

Two fertile bulls were placed into each pasture 11 d after TAI and were removed 50 d later. Pregnancy diagnosis was made by transrectal ultrasonography 33 d after TAI. Cows and calves were weighed and cows were assigned a BCS 67 d after TAI. Final pregnancy rates were diagnosed in October by palpation per rectum.

Statistics

*Trials 1and 2.*Cow and calf performance were analyzed as a completely-randomized design (PROC MIXED; SAS Inst. Inc., Cary, NC). All animals were maintained in single pens or pastures for the duration of the studies; therefore, individual animal was considered the experimental unit. The model included an effect for treatment only. When protected by a significant F-test ($P < 0.05$), least-squares treatment means were separated using the method of Least Significant Difference.

Pregnancy rates and cyclicity were analyzed using logistic regression (PROC GLIMMIX; SAS Inst. Inc., Cary, NC). The model used to assess differences in timed AI pregnancy rates and overall pregnancy rates included effects for treatment, parity, technician, cycling status, and all appropriate interactions. Least-squares treatment means for pregnancy rates were reported. When protected by a significant F-test ($P < 0.05$), least-squares treatment means were separated using the method of Least Significant Difference. Treatment differences in performance and pregnancy data were discussed when $P \leq 0.05$.

Trial 3. Cow and calf performance were analyzed as a randomized complete block (PROC MIXED; SAS Inst. Inc., Cary, NC). The model included effects for treatment, pasture, location, and treatment within pasture. Treatment within pasture was used as the error term. When protected by a significant F-test ($P < 0.05$), least-squares treatment means were separated using the method of Least Significant Difference.

Pregnancy rates and cyclicity were analyzed using logistic regression (PROC GLIMMIX; SAS Inst. Inc., Cary, NC). The model used to assess differences in timed AI pregnancy rates and overall pregnancy rates included effects for treatment, parity, technician, pasture, cycling status, and all appropriate interactions. Least-squares treatment means for pregnancy rates were reported. When protected by a significant F-test ($P < 0.05$), least-squares treatment means were separated using the method of Least Significant Difference. Treatment differences in performance and pregnancy data were discussed when $P \leq 0.05$.

Results and Discussion

Trial 1. Cow BW and BCS on d 0 were not different ($P \geq 0.77$) between treatment groups (Table 3.3). Furthermore, cow BW and BCS were unaffected ($P \geq 0.14$) by treatment on d 50, at calving, on d 120, and on d 146.Similarly, supplementation of dairy cows for 25 d pre-partum with 15 g/cow RPC daily (had no effect on BW, BCS, or DMI (Janovick-Guretzky et al., 2006). Erdman and Sharma (1991) reported that RPC supplementation of dairy cows from wk 5 post-partum to wk 21 post-partum had no effect on average BW or DMI. Zahra and co-workers (2006) also reported that supplementation of dairy cows with 14 g/cow RPC daily had no effect on pre-partum DMI. Interestingly, these researchers observed that DMI of thin cows (BCS < 4) was not altered by RPC supplementation but that fat cows (BCS ≥ 4) receiving RPC had greater DMI than unsupplemented cows. Beef steers fed 5 g/d dietary choline daily had increased ADG compared to unsupplemented steers but this response was diminished with increasing RPC feeding levels (Bryant et al., 1999). Beef heifers fed a finishing diet containing RPC at either 0, 5, 10 or 15 g/d had greater DMI than control heifers for only the first 30 d of exposure; however, ADG and gain efficiency were improved for RPC-supplemented heifers for120 d (Bindel et al., 2000).

The proportion of cows that conceived to fixed-timed AI was not different between treatments (*P* = 0.11; Table 3.3); moreover, overall pregnancy was not different (*P* = 0 .49) between treatments. Dairy cows receiving either 15, 30, or 45 g/d dietary choline from wk 5 post-partum to wk 21post-partum required more services per cow and were open more days compared to unsupplemented cows (Erdman and Sharma, 1991). These authors also reported increased milk yield due to RPC supplementation and concluded that reproductive responses were more related to increased milk production.

Cow BF on d 0, on d 50, at calving, on d 120, and on d 146 were not different (*P* ≥ 0.29) between RPC- or CON-supplemented cows; moreover, Cow BF change (d 0 to d 146) was not different (*P* = 0.42) between treatments (Table 3.4). Cow LMD was not different (*P* ≥ 0.11) between treatments on d 0, on d 50, at calving, or on d 146; however, LMD was greater (*P* = 0.04) for RPC-supplemented cows than CON-supplemented cows on d 120 (50.4 vs. 48.3 mm, respectively). Conversely, CON-supplemented cows had more favorable (*P* = 0.04) change in LMD than RPC-supplemented cows from d 0 to d 146 (-0.9 vs. -4.2 mm, respectively). Cow IMF on d 0, on d 50, at calving, and on d 146 or cow IMF change from d 0 to d 146 were not different (*P* ≥ 0.10) between RPC- and CON-supplemented cows. In contrast, CON-supplemented cows had greater (*P* = 0.01) IMF scores than RPC-supplemented cows on d 120 (6.3 vs. 6.0, respectively). Pinotti and coworkers (2003) observed a post-partum increase in plasma NEFA and a post-partum decrease in NEFA:cholesterol in RPC-supplemented dairy cows compared to CON-supplemented dairy cows. Authors speculated that increased plasma NEFA led to increased uptake by the liver.

In the liver, NEFA are esterified to triglycerides, oxidized to ketone bodies, or oxidized to carbon dioxide. The esterification of NEFA to triglycerides and their export via VLDL involves choline. In addition, choline serves as a methyl donor for the synthesis of carnitine; carnitine is essential for fatty acid oxidation. The lesser plasma NEFA of RPC-supplemented cows reported by Pinotti and coworkers (2003) may have resulted from more efficient liver function and improved lipid metabolism. These data could explain why RPC-supplemented cows in our study had lesser IMF on d 120, subsequent to calving, than CON-supplemented cows.

Supplementation of dams with RPC had no effect ($P \geq 0.71$) on calf BW at birth, on d 146 or on d 256 (Table 3.5). Calf ADG from d 146 to d 256, calf ADG from birth to d 256, and adjusted 205-d BW were not different ($P \geq 0.23$) between treatments. Conversely, calves from CON-supplemented cows tended (*P* = 0.07) to have greater ADG from birth to d 146 than calves from RPC-supplemented cows (1.0 vs. 0.9 kg/d, respectively). Zahra and co-workers (2006) reported that peri-parturient dairy cows with BCS ≥ 4 had greater milk production when supplemented with 14 g RPC/cow daily compared to no RPC. Likewise, Pinotti and co-workers (2003) observed increased milk production following RPC supplementation (20 g/cow daily) of peri-parturient dairy cows with. In contrast, Zahra and coworkers (2006) reported that thin cows (BCS < 4) supplemented with RPC had similar milk production to unsupplemented cows. Cows in our study had an initial average BCS of 5.7 and final average BCS of 5.7. These BCS may not have been adequate to provoke an increase in milk production that was previously observed in fleshy dairy cows.

Trial 2. Cow BW, cow BW change, cow BCS, and cow BCS change during the supplement feeding period were not affected by treatment ($P \geq 0.20$; Table 3.6). Treatment did not affect ($P \geq 0.18$) change in BF, IMF, or LMD (Table 3.7). Calf BW at birth and at d 250 were not different ($P \geq 0.25$) between treatment groups (Table 3.8). In addition, calf ADG (birth to d 250) and adjusted 205-d BW were not different ($P \geq 0.71$) between treatments. Conception to fixed-time AI was numerically more favorable ($P = 0.11$) for RPC (58.4%) than for CON (45.7%; Table 3.6); however, final pregnancy rates were similar ($P = 0.46$) between CON and RPC (92.8 vs.89.0, respectively).

Trial 3. Cow BW and BCS were not different ($P \geq 0.13$) between treatments on d 0, on d 60, on d 125, on d 190, or on d 250, relative to the beginning of the study (Table 3.9). At calving, RPC-supplemented cows were substantially heavier ($P = 0.01$) than CON-supplemented cows (569 vs. 496 kg, respectively) but cow BCS at calving was unaffected by treatment ($P = 0.53$).

Cow BF, LMD, and IMF were not different ($P \geq 0.35$) between treatments on d 0 or at the end of the supplementation period (d 60; Table 3.10). Cow BF change and IMF change from d 0 to d 60 were not different ($P \geq 0.39$) between treatments. Conversely, LMD change from d 0 to d 60 tended to be ($P = 0.10$) more favorable for CON-supplemented cows than RPC-supplemented cows (-0.2 vs. -1.1 mm, respectively). Timed-AI and overall pregnancy rates were not different (P ≥ 0.33) between treatments.

Adjusted calf 205-d BW were not different ($P = 0.51$) between treatments (Table 3.11). Calf ADG during the first portion of the summer grazing season (birth to d 125) was not different ($P \geq 0.14$) between treatments; however, calf ADG from d 125 to weaning (d 250) tended to be greater (P = 0.09) for calves of RPC-supplemented cows than for calves of CON-supplemented cows. Overall calf ADG (birth to weaning) was not different (P = 0.51) between treatments. Erdman and Sharma (1991) reported that choline supplementation of dairy cows resulted in greater milk yields. This may explain why calves of RPC-supplemented cows in our study had improved ADG during the latter portion of the grazing season; however, this did not translate to greater 205-d calf BW or improved birth-to-weaning ADG.

Implications

Supplementation of beef cows with RPC during the pre-partum period had varying effects on cow BW, BW change, BCS, BCS change, backfat thickness, longissimus-muscle depth, and degree of intramuscular fat. Calves suckled by RPC-supplemented dams had greater ADG in some instances; however, adjusted 205-d BW were not affected by pre-partum RPC supplementation of dams. Under the conditions of our studies, pre-partum RPC supplementation had minimal effects on performance of beef cows and calves.

Tables

Table 3.1. Composition of ruminally-protected choline (RPC) and control supplements supplied to pre-partum beef cows consuming forage sorghum hay *ad libitum* (Trials 1[*] & 2[†])

	Treatment group	
Ingredient, % DM	**Control**	**RPC**
Ground sorghum grain	69.1	68.3
Soybean meal	25.0	25.0
Trace mineral supplement	5.9	5.9
Ruminally-protected choline premix[‡]	-	0.8

[*] In trial 1, cows were supplemented for 120 d; supplementation commenced 50 d prior to the first expected calving date.

[†] In trial 2, cows were supplemented 40 d; supplementation commenced 40 d prior to the first expected calving date and ended when the first cow calved.

[‡] Premix contained 264 g ruminally-protected choline per kg and was mixed at a rate of 6933 g / 907 kg complete supplement.

Table 3.2. Composition of ruminally-protected choline (RPC) and control supplements supplied to pre-partum beef cows grazing dormant, warm-season native forage (Trial 3*)

	Treatment group	
Ingredient, % DM	**Control**	**RPC**
Ground corn	25.0	24.2
Soybean meal	75.0	75.0
Ruminally-protected choline premix[†]	-	0.8
Composition, % DM		
DM, %	89.2	88.6
CP, %	40.7	37.1
Ca, %	0.30	0.22
P, %	0.57	0.54
NDF, %	10.26	9.91
ADF, %	4.27	4.45
Starch, %	12.35	15.78

[*] Cows were supplemented 60 d; supplementation commenced 60 d prior to the first expected calving date and ended when the first cow calved.

[†] Premix contained 264 g ruminally-protected choline per kg and was mixed at a rate of 6933 g / 907 kg complete supplement.

Table 3.3. Performance of beef cows fed forage-sorghum hay *ad libitum* and supplemented with ruminally-protected choline (RPC) or an isocaloric, isonitrogenous control supplement (CON) beginning 50 d before the first expected calving date and continuing thereafter for 120 d (Trial 1)

Item	CON	RPC	SE	P
Cow BW (d 0), kg	651	654	6.6	0.77
Cow BW (d 50), kg	669	676	6.7	0.46
Cow BW (at calving), kg	601	601	6.6	0.97
Cow BW (d 120), kg	578	565	6.4	0.14
Cow BW (d 146), kg	613	611	6.6	0.84
Cow BW change (d 0 to 146), kg	-36.8	-43.2	3.38	0.17
Cow BCS (d 0),	5.7	5.8	0.07	0.84
Cow BCS (d 50),	5.4	5.4	0.08	0.89
Cow BCS (at calving),	5.2	5.2	0.08	0.65
Cow BCS (d 120),	5.3	5.3	0.09	0.95
Cow BCS (d 146),	5.7	5.8	0.09	0.64
Cow BCS change (d 0 to 146), kg	0.0	0.0	0.08	0.62
Timed-AI Pregnancy (%)	40.7	52.9	0.05	0.11
Overall Pregnancy (%)	91.4	94.1	0.02	0.49

Table 3.4. Ultrasonically-measured body composition of beef cows fed forage-sorghum hay *ad libitum* and supplemented with ruminally-protected choline (RPC) or an isocaloric, isonitrogenous control supplement (CON) beginning 50 d before the first expected calving date and continuing thereafter for 120 d (Trial 1)

Item	CON	RPC	SE	P
Cow 12^{th}-rib back fat (d 0), mm	6.5	6.4	0.22	0.76
Cow 12^{th}-rib backfat (d 50), mm	6.2	5.9	0.25	0.51
Cow 12^{th}-rib backfat (calving), mm	5.2	5.1	0.21	0.75
Cow 12^{th}-rib backfat (d 120), mm	5.1	4.8	0.22	0.29
Cow12^{th}-rib backfat (d 146), mm	4.7	4.8	0.23	0.75
Cow 12^{th}-rib backfat change (d 0 to 146), mm	-1.8	-1.6	0.22	0.42
Cow 12^{th}-rib longissimus muscle depth (d 0), mm	53.2	54.6	0.98	0.33
Cow 12^{th}-rib longissimus muscle depth (d 50), mm	51.4	52.2	0.71	0.43
Cow 12^{th}-rib longissimus muscle depth (calving), mm	49.4	51.0	0.75	0.11
Cow 12^{th}-rib longissimus muscle depth (d 120), mm	48.3	50.4	0.73	0.04
Cow 12^{th}-rib longissimus muscle depth (d 146), mm	51.9	50.4	0.79	0.17
Cow 12^{th}-rib longissimus muscle depth change (d 0 to 146), mm	-0.9	-4.2	1.16	0.04
Cow intra-muscular fat score (d 0)*	5.3	5.2	0.08	0.23
Cow intra-muscular fat score (d 50)*	5.8	5.8	0.08	0.78
Cow intra-muscular fat score (calving)*	5.8	6.0	0.08	0.10
Cow intra-muscular fat score (d 120)*	6.3	6.0	0.08	0.01
Cow intra-muscular fat score (d 146)*	6.3	6.3	0.08	0.46
Cow intra-muscular fat score change (d 0 to 146)	1.0	1.2	0.10	0.14

* Marbling scores were assigned as described by Brethour (1994): (Trace 00 = 3.00, Slight 00 = 4.00, Small 00 = 5.00, Modest 00 = 6.00, Moderate 00 = 7.00).

Table 3.5. Performance of beef calves born to beef cows fed forage-sorghum hay *ad libitum* and supplemented with ruminally-protected choline (RPC) or an isocaloric, isonitrogenous control supplement (CON) beginning 50 d before the first expected calving date and continuing thereafter for 120 d (Trial 1)

Item	CON	RPC	SE	P
Calf BW (birth), kg	41.0	40.9	0.51	0.81
Calf BW (d 146), kg	95.8	94.6	2.32	0.71
Calf BW (d 256), kg	221.4	220.6	3.30	0.86
Early ADG (birth to d 146), kg	1.0	0.9	0.02	0.07
Late ADG (d 146 to d 256), kg	1.1	1.1	0.01	0.84
Overall ADG (birth to 256), kg	1.1	1.1	0.01	0.30
Adjusted 205-d BW, kg	270	264	3.1	0.23

Table 3.6. Performance of beef cows fed forage-sorghum hay *ad libitum* and supplemented with ruminally-protected choline (RPC) or an isocaloric, isonitrogenous control supplement (CON) for 40 d before the first expected calving date (Trial 2)

Item	CON	RPC	SE	P
Cow BW (d 0), kg	604	609	6.0	0.57
Cow BW (d 80), kg	573	574.30	6.7	0.86
Cow BW change (d 0 to 80), kg	31.1	34.3	4.02	0.57
Cow BCS (d 0),	5.7	5.8	0.05	0.20
Cow BCS (d 80),	5.0	5.0	0.06	0.63
Cow BCS change (d 0 to 80), kg	-0.7	-0.8	0.07	0.66
Timed-AI Pregnancy (%)	45.7	58.4	0.05	0.11
Overall Pregnancy (%)	92.8	89.0	0.03	0.44

Table 3.7. Ultrasonically-measured body composition of beef cows fed forage-sorghum hay *ad libitum* and supplemented with ruminally-protected choline (RPC) or an isocaloric, isonitrogenous control supplement (CON) for 40 d before the first expected calving date (Trial 2)

Item	CON	RPC	SE	P
Cow 12th-rib backfat (d 0), mm	4.0	4.0	0.16	0.95
Cow 12th-rib backfat (d 80), mm	3.5	3.8	0.12	0.09
Cow 12th-rib backfat change (d 0 to 80), mm	-0.4	-0.1	0.15	0.18
Cow 12th-rib longissimus muscle depth (d 0), mm	42.8	45.3	0.95	0.06
Cow 12th-rib longissimus muscle depth (d 80), mm	41.4	41.8	0.52	0.59
Cow 12th-rib longissimus muscle depth change (d 0 to 80), mm	-1.4	-3.5	1.03	0.15
Cow intra-muscular fat score (d 0) *	3.8	3.8	0.05	0.39
Cow intra-muscular fat score (d 80) *	5.6	5.8	0.09	0.26
Cow intra-muscular fat score change (d 0 to 80)	1.8	2.0	0.09	0.49

* Marbling scores were assigned as described by Brethour (1994): (Trace 00 = 3.00, Slight 00 = 4.00, Small 00 = 5.00, Modest 00 = 6.00, Moderate 00 = 7.00).

Table 3.8. Performance of beef calves born to beef cows fed forage-sorghum hay *ad libitum* and supplemented with ruminally-protected choline (RPC) or an isocaloric, isonitrogenous control supplement (CON) for 40 d before the first expected calving date (Trial 2)

Item	CON	RPC	SE	P
Calf BW (birth), kg	36.0	35.8	0.60	0.75
Calf BW (d 250), kg	201.8	207.5	3.54	0.25
Overall ADG (birth to d 250), kg	1.1	1.1	0.01	0.67
Adjusted 205-d BW, kg	260	262	3.1	0.71

Table 3.9. Performance of beef cows grazing dormant, warm-season native range and supplemented with ruminally-protected choline (RPC) or an isocaloric, isonitrogenous control supplement (CON) for 60 d before the first expected calving date (Trial 3)

Item	CON	RPC	SE	P
Cow BW (d 0), kg	528	537	6.0	0.30
Cow BW (d 60), kg	513	516	6.7	0.72
Cow BW (at calving), kg	496	569	21.6	0.01
Cow BW (d 125), kg	539	545	6.8	0.50
Cow BW (d 190), kg	569	576	6.2	0.38
Cow BW (d 250), kg	577	584	6.2	0.42
Cow BW change (d 0 to 250), kg	6.3	7.9	9.3	0.90
Cow BCS (d 0),	5.2	5.2	0.03	0.94
Cow BCS (d 60),	4.7	4.7	0.04	0.93
Cow BCS (at calving),	4.9	4.8	0.05	0.53
Cow BCS (d 125),	5.7	5.6	0.05	0.13
Cow BCS (d 190),	5.4	5.4	0.06	0.94
Cow BCS (d 250),	5.5	5.4	0.05	0.46
Cow BCS change (d 0 to 250), kg	0.3	0.2	0.06	0.24
Timed-AI Pregnancy (%)	40.7	34.8	0.04	0.33
Overall Pregnancy (%)	92.0	89.9	0.03	0.62

Table 3.10. Ultrasonically-measured body composition of beef cows grazing dormant, warm-season native range and supplemented with ruminally-protected choline (RPC) or an isocaloric, isonitrogenous control supplement (CON) for 60 d before the first expected calving date (Trial 3)

Item	CON	RPC	SE	P
Cow 12th-rib backfat (d 0), mm	3.2	3.3	0.06	0.61
Cow 12th-rib backfat (d 60), mm	3.2	3.2	0.06	0.54
Cow 12th-rib backfat change (d 0 to 60), mm	0.0	-0.1	0.06	0.88
Cow 12th-rib longissimus muscle depth (d 0), mm	42.3	42.7	0.35	0.48
Cow 12th-rib longissimus muscle depth (d 60), mm	42.1	41.6	0.41	0.43
Cow 12th-rib longissimus muscle depth change (d 0 to 60), mm	-0.2	-1.1	0.37	0.10
Cow intra-muscular fat score (d 0)	4.9	4.9	0.04	0.97
Cow intra-muscular fat score (d 60)	4.5	4.6	0.05	0.35
Cow intra-muscular fat score change (d 0 to 60)	-0.4	-0.3	0.06	0.39

* Marbling scores were assigned as described by Brethour (1994): (Trace 00 = 3.00, Slight 00 = 4.00, Small 00 = 5.00, Modest 00 = 6.00, Moderate 00 = 7.00).

Table 3.11. Performance of beef calves born to beef cows grazing dormant, warm-season native range and supplemented with ruminally-protected choline (RPC) or an isocaloric, isonitrogenous control supplement (CON) for 60 d before the first expected calving date (Trial 3)

Item	CON	RPC	SE	P
Calf BW (birth), kg	39.5	39.4	0.47	0.91
Calf BW (d 125), kg	93.1	94.8	1.54	0.43
Calf BW (d 250), kg	228.1	231.9	2.91	0.34
Early ADG (birth to d 125), kg	1.1	1.1	0.01	0.14
Late ADG (d 125 to d 250), kg	1.1	1.0	0.02	0.09
Overall ADG (birth to d 250), kg	1.1	1.1	0.01	0.51
Adjusted 205-d BW, kg	262	265	3.3	0.51

Literature Cited

Bindel, D. J., J. S. Drouillard, E. C. Titgemeyer, R. H.Wessels, and C. A. Löest. 2000. Effects of Ruminally-protected choline and dietary fat on performance and blood metabolites of finishing heifers. J. Anim. Sci. 78:2497-2503.

Brethour, J. R. 1994. Estimating marbling score in live cattle from ultrasound images using pattern recognition and neural network procedures. J. Anim. Sci. 72:1425-1432.

Bryant, T. C., J. D. Rivera, M. L. Galyean, G. C. Duff, D.M. Hallford, and T. H. Montgomery. 1999. Effects of dietary level of ruminally-protected choline on performance and carcass characteristics of finishing beef steers and on growth and serum metabolites in lambs. J. Anim. Sci. 77:2893-2903.

Erdman, R. A., and B. K. Sharma. 1991. Effects of dietary ruminally-protected choline in lactating dairy cows. J. Dairy Sci. 74:1641-1647.

Janovick-Guretzky, N. A., D. B. Carlson, J. E. Garrett, and J. K. Drackley. 2006. Lipid metabolite profiles and milk production for Holstein and Jersey cows fed ruminally-protected choline during the peri-parturient period. J. Dairy Sci. 89:188-200.

Pinotti, L., A. Baldi, I. Politis, R. Rebucci, L. Sangalli, and V. Dell'Orto. 2003. Ruminally-protected choline administration to transition cows: effects on milk production and vitamin E status. J. Vet. Med. Assoc. 50:18-21.

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

Zahra, L. C., T. F. Duffield, K. E. Leslie, T. R. Overton, D. Putnam, and S. J. LeBlanc. 2006. Effects of ruminally-protected choline and monensin on milk production and metabolism of periparturient dairy cows. J. Dairy Sci. 89:4808-4818.

Chapter 4 - **Effects of co-grazing on herbivory patterns and performance by cattle and goats grazing native tallgrass rangeland infested by sericea lespedeza (*Lespedeza cuneata*)**

L. A. Pacheco, W. H. Fick, E. A. Bailey, D. L. Davis, G. W. Preedy, and K. C. Olson

Abstract

Lactating crossbred cows with calves (n=145; initial BW = 579 ± 91 kg) and non-pregnant, non-lactating Boer-cross nannies (n = 200; initial BW = 42 ± 1.9 kg) were used to evaluate the effects of co-grazing on herbivory patterns and animal performance while grazing native tallgrass rangeland infested heavily by sericea lespedeza (**SL**; average SL biomass in October = 2,061 kg/ha). Nine pastures were assigned randomly to 1 of 2 grazing systems: 5 pastures (65 ha) were grazed by cows + calves only (single-species; 0.8 ha/AUM) and 4 pastures (32 ha) were grazed by cows + calves (0.8 ha/AUM) and goats (multispecies; 0.8 ha/AUE monthly). Cows + calves and goats were assigned randomly to pastures. Animal BW was measured at 28-d intervals from June 1 to October 1; BCS were assigned to cows also at those times. Two permanent 100-m transects were marked at the onset of the trial (June 15) within each pasture to estimate botanical composition and SL herbivory. Seasonlong cow BW change, seasonlong calf ADG, and cow pregnancy rates were not different ($P \geq 0.08$) between multispecies and single-species pastures. Conversely, seasonlong cow BCS change was greater ($P < 0.01$) on multispecies pastures than on single-species pastures (0.04 vs. -0.38, respectively). Biomass of SL was not different ($P = 0.97$) between pastures at the outset of the study. The percentage of individual SL plants that had been grazed at the end of the trial was greater ($P < 0.01$) on multispecies pastures than on single-species pastures (94.2 vs. 77.5%, respectively). Final SL biomass in multispecies pastures averaged 1,692 kg/ha, whereas final SL biomass in single-species pastures averaged 2,230 kg/ha (SE = 739.4 kg; $P = 0.37$). Residual forage biomass at the end of the trial was not different ($P = 0.54$) between treatments and averaged 3,622 kg/ha, indicating that forage availability did not limit forage intake during our trial. Our results were interpreted to suggest that grazing cows and goats in combination increased grazing pressure on SL without negatively affecting beef cow performance, beef calf performance, or residual forage biomass.

Key Words: beef cows, goats, *Lespedeza cuneata*, multispecies grazing

Introduction

Sericea lespedeza (*Lespedeza cuneata;* SL), a perennial legume, was first introduced into the United States in the 1890s from Japan. Agronomists quickly learned that it was an adaptable plant, tolerant of shallow, acidic, or low-fertility soils. Furthermore, SL was relatively resistant to insects and disease. These factors made SL a popular choice for reseeding strip-mined areas, highway right-of-ways, dams, and waterways in the US for nearly a century.

Sericea lespedeza, a highly competitive and prolific seed producer, is capable of producing 481 to 950 kg of seed / ha annually (Vermeire et al., 2007). Vigorous seed production allows SL to rapidly infiltrate native grasslands that are adjacent to reseeding projects. In Kansas alone, this plant infests over 600,000 acres of pasture, reducing native grass production by up to 92% (Eddy et al., 2003).

Sericea lespedeza, when mature, contains high levels of condensed tannins (Eckerle et al., 2010). Condensed tannins reduce protein digestion by ruminants and are a strong deterrent to consumption (Jones and Mangan, 1977; Eckerle et al., 2011a, 2011b, and 2011c). Poor intake of SL translates to negligible grazing pressure by beef cattle, which ensures that it will be able to produce seed and continue to proliferate.

Increasing grazing pressure on SL may slow its advance and allow a measure of biological control. Goats voluntarily consume forages and browse high in tannins. Furthermore, they are commonly used for removal of undesirable plants that are avoided by larger domestic herbivores. Therefore, the objective of our study was to evaluate the effects of co-grazing on herbivory patterns and performance by cattle and goats grazing native tallgrass rangeland infested by sericea lespedeza.

Materials and Methods

All procedures were approved by the Kansas State University Animal Care and Use Committee (protocol no. 2978). Nine pastures that were heavily infested with SL were randomly assigned to 1 of 2 grazing systems: 5 pastures (65 ha) were grazed by cows + calves only (single-species; 0.8 ha/AUM) and 4 pastures (32 ha) were grazed by cows + calves (0.8 ha/AUM) and goats (multispecies; 0.8 ha/AUE monthly).

Lactating, crossbred cows with calves (n = 145; initial BW = 579 ± 91 kg) were blocked by age and calving date and randomly assigned to 1 of 2 grazing systems: single-species (**SS**) or multispecies (**MS**). Non-pregnant, non-lactating Boer-cross nannies (n = 200; initial BW = 42 ± 1.9 kg) were randomly assigned to 1 of 4 MS pastures. Animal BW was measured at 28-d intervals from June 1 to October 1; BCS (1 = emaciated, 9 = obese; Wagner et al., 1988) were assigned to cows also at those times. Cattle were allowed to graze pastures freely for the duration of the trial. Pregnancy rate was determined via rectal palpation at the end of the season. Goats were allowed to graze in their respective pastures each day from 0700 until 1400. During the evening and nighttime hours, they were confined to a pen to prevent predation.

Two permanent 100-m transects were marked at the onset of the trial (June 15) within each pasture to estimate above-ground forage biomass, botanical composition, and SL herbivory. Total forage biomass was estimated by clipping forage biomass at a height of 1 cm from within randomly-placed sampling frames (0.25 m^2; n = 10/pasture). Average total biomass of SL ranged from a low of 206 kg/ha to a high of 2,024 kg/ha during the grazing season. Plant-species composition was estimated using a modified step-point technique (Owensby, 1973; Table 4.1). Herbivory of individual SL plants was estimated visually at the end of the study (October 15).

Individual SL plants were considered grazed if they were examined to be truncated or defoliated by grazing.

Statistics

Cow and calf performance and forage biomass were analyzed as a completely randomized design (PROC MIXED; SAS Inst. Inc., Cary, NC). The model included terms for treatment, period, and treatment × period. Treatment × period effects were not detected; therefore, main effects of treatment were reported as least-squares means.

Reproductive responses were analyzed via logistic regression (PROC CATMOD; SAS Inst. Inc., Cary, NC). Sericea lespedeza herbivory as analyzed via the Chi-square procedure. Means were considered to be different when $P \leq 0.05$. Tendencies were discussed when $P > 0.05$ and < 0.10).

Results and Discussion

Cow and Calf Performance

Cow BW change from d 0 to d 56 of our study was greater ($P = 0.01$) for cows in SS pastures than in MS pastures; SS cows gained 19.5 ± 11.55 kg more BW than MS cows (Table 4.2). Cow BW change from d 56 to d 112 was not different ($P = 0.32$) between treatments; however, SS cows tended ($P = 0.08$) to have greater BW change from d 0 to d 112 than MS cows. In contrast, Webb et al. (2008) reported no difference in ADG between steers grazing in single-species pastures compared to steers co-grazing with goats. Greater BW change was not related to a change in pregnancy percentage. Pregnancy rate was not different ($P = 0.40$) between treatments (Table 4.2).

The pattern in cow BCS change was opposite that of BW change (Table 4.1). Cow BCS change from d 0 to 56 was greater ($P = 0.01$) for MS pastures than for SS pastures (0.42 vs. -0.05, respectively), whereas, cow BCS change from d 56 to day 112 was not different (*P* = 0.52) between SS and MS. In contrast, cow BCS change from d 0 to 112 was greater (*P*< 0.01) for MS pastures than on SS pastures (0.04 vs. -0.38, respectively). We speculated that the conflicting trends in cow BW and cow BCS were driven by differences in gut fill. Cows grazing SS pastures may have had poorer quality diets (particularly from a protein perspective) than cows grazing MS pastures. This condition may have caused greater gut fill and greater BW change among cows on SS pastures that did not translate to greater BCS. Calf performance provided evidence to support this speculation (Table 4.2). Calf ADG was similar (*P* ≥ 0.14) between treatments from d 0 to d 56 and from d 0 to 112; however, calf ADG in MS pastures was greater (*P* = 0.01) in SS pastures from d 56 to d 112, at a time when forages were most mature and, typically, of poor relative quality.

Herbivory

Biomass of SL was not different (*P* = 0.97) between SS and MS pastures at the outset of the study (Table 4.3). The percentage of individual SL plants that had been grazed at the end of the trial was greater (*P* < 0.01) on MS pastures than on SS pastures (94.2 vs. 77.5%, respectively). Other researchers reported similar findings (Webb et al., 2008; Abaye et al., 2009). Abaye et al. (2009) suggested that greater grazing pressure on SL in MS pastures caused SL plants to remain in a vegetative state (i.e., with lesser concentrations of condensed tannins; Eckerle et al., 2010) than SL in SS pastures. Furthermore, they reported that cattle maintained on MS pastures continued to graze SL later into the season than cattle maintained on SS pastures.

Final SL biomass in MS pastures averaged 1,692 kg/ha, whereas final SL biomass in SS pastures averaged 2,230 kg/ha (SE = 739.4 kg; *P* = 0.37). Residual forage biomass at the end of the trial was not different (*P* = 0.54) between treatments and averaged 3,622 kg/ha. Based on this figure, we concluded that forage availability did not limit forage intake by either cattle or goats during our study. Webb et al. (2008) reported that season-ending forage biomass was less for MS pastures than for SS pastures; however, stocking densities in that study were typical of improved pastures and were 5 × greater than those employed in our study.

Implications

Our results were interpreted to suggest that grazing cows and goats in combination may increase grazing pressure on SL without negatively affecting beef cow or beef calf performance or residual forage biomass. Sericea lespedeza was grazed more frequently in pastures with a full stocking-rate complement of cattle and goats (i.e, 0.8 AUM or AUE/ha for both species) than in pastures stocked with cattle alone (i.e., 0.8 AUM for cattle only).

Table 4.1. Plant-species composition in pastures grazed by beef cows, beef calves, and goats during a summer grazing season (June 15 to October 15)

Treatment	**Multispecies***				**Single-species***				
Pasture no.	**1**	**5**	**8**	**9**	**2**	**3**	**4**	**6**	**7**
Grasses†, % frequency									
Andropogon gerardii	20.5	23.5	33.5	12.0	16.0	20.0	13.0	17.0	20.0
Sorghastrum nutans	14.0	3.5	6.5	10.5	14.5	6.0	5.5	7.5	7.0
Schizachyrium scoparium	17.0	11.0	17.5	12.5	11.0	26.0	16.5	20.5	14.5
Dichanthelium oligosanthes	7.0	2.0	4.0	9.5	6.5	7.0	5.5	2.0	5.0
Carex spp.	11.5	11.5	13.0	16.0	8.5	10.0	16.0	18.5	17.5
Sporobolus asper	4.5	9.0	3.5	6.0	3.0	6.0	2.5	4.0	6.0
Cynodon dactylon	0.0	5.0	0.0	0.5	0.0	0.5	0.0	0.0	0.0
Bouteloua hirsuta	1.5	2.0	0.0	6.0	1.5	0.5	3.0	0.5	0.0
Other grasses	7.0	9.0	9.0	14.5	15.0	6.5	19.5	11.5	19.0
Total grasses	83.0	76.5	87.0	87.5	76.0	82.5	81.5	81.5	89.0
Forbs†, % frequency									
Lespedeza cuneata	3.2	0.9	0.0	0.1	1.2	1.3	1.3	0.5	0.2
Lespedeza virginica	1.0	1.5	0.6	0.7	0.3	0.5	0.4	0.9	0.0
Kummerowia stipulacea	1.1	0.5	0.2	0.4	1.8	0.3	0.2	0.3	0.3
Ambrosia psilostachya	1.5	1.3	2.0	0.8	1.6	1.5	1.0	2.0	1.1
Achillea millefolium	0.8	1.0	0.1	0.4	0.9	0.6	0.1	0.1	0.1
Ambrosia bidentata	0.0	1.8	1.2	3.2	5.6	0.8	2.9	1.8	4.2
Other forbs	9.3	16.7	8.9	7.0	12.6	12.6	12.8	12.9	5.2
Total forbs	17.0	23.5	13.0	12.5	24.0	17.5	18.5	18.5	11.0

* Single-species pastures (65 ha) were grazed by cows + calves only (0.8 ha/AUM) and multispecies pastures (32 ha) were grazed by cows + calves (0.8 ha/AUM) and goats (0.8 ha/AUM).

† Plant-species composition was estimated using a modified step-point technique (Owensby, 1973).

Table 4.2. Effects of co-grazing on performance of beef cows, calves, and goats grazing native tallgrass pastures heavily infested with sericea lespedeza during a summer grazing season (June 15 to October 15)

Item	Multispecies Pastures*	Single-species Pastures*	SE	P
Cow BW change (d 0 to 56), kg	19.0	38.5	5.30	0.01
Cow BW change (d 56 to 112), kg	14.9	8.6	4.70	0.32
Cow BW change (d 0 to 112), kg	33.6	47.6	6.90	0.08
Cow BCS† change (d 0 to 56)	0.42	-0.05	0.097	0.01
Cow BCS† change (d 56 to 112)	-0.38	-0.32	0.085	0.52
Cow BCS† change (d 0 to 112)	0.04	-0.38	0.092	< 0.01
Cow pregnancy rate‡, %	77.5	83.8	6.60	0.40
Calf ADG (d 0 to 56), kg	1.18	1.26	0.044	0.14
Calf ADG (d 56 to 112), kg	0.53	0.44	0.031	0.01
Calf ADG (d 0 to 112), kg	0.89	0.90	0.027	0.86
Goat ADG (d 0 to 112), kg	0.17	-	-	-

* Single-species pastures (65 ha) were grazed by cows + calves only (0.8 ha/AUM) and multispecies pastures (32 ha) were grazed by cows + calves (0.8 ha/AUM) and goats (0.8 ha/AUE monthly).

† Body condition scores were assigned on a scale of 1-9 (1 = emaciated, 9 = obese; Wagner et al.,1988).

‡ Pregnancy was determined via rectal palpation 60 d after the conclusion of the breeding season.

Table 4.3. Effects of co-grazing on herbivory patterns by beef cows, beef calves, and goats grazing native tallgrass pastures heavily infested with sericea lespedeza during a summer grazing season (June 15 to October 15)

Item	Multispecies Pastures*	Single-species Pastures*	SE	P
Total SL plants grazed, %	94.2	77.5	-	0.01
Initial SL biomass, kg/ha	253	278	739.4	0.97
Final SL biomass, kg/ha	1,692	2,230	739.5	0.37
Initial total forage biomass, kg/ha	1,451	2,306	794.9	0.43
Final total forage biomass, kg/ha	3,253	3,918	794.9	0.54

* Single-species pastures (65 ha) were grazed by cows + calves only (0.8 ha/AUM) and multispecies pastures (32 ha) were grazed by cows + calves (0.8 ha/AUM) and goats (0.8 ha/AUE monthly).

Literature Cited

Abaye, O., M. Webb and C. Zipper. 2009. The influence of cattle grazing alone and with goats on forage biomass, botanical composition, and browse species on reclaimed coal-mine pastures. In Proc., Southern Conservation Agricultural Systems Conference, pp 28-35. Department of Crop and Soil Environmental Sciences - Eastern Shore Agricultural Research and Extension Center, Virginia Polytechnic Institute and State University.

Eckerle, G. J., K. C. Olson, J. R. Jaeger, J. W. Waggoner, J. L. Davidson and L. A. Pacheco. 2011a. High-tannin forage utilization by beef cows I. Intake and digestion of Tallgrass prairie hay contaminated with sericea lespedeza (*Lespedeza cuneata*). Proc. West. Sec. Amer. Soc. Anim. Sci. 62:199-202.

Eckerle, G. J., K. C. Olson, J. R. Jaeger, J. W. Waggoner, J. L. Davidson and L. A. Pacheco. 2011b. High-tannin forage utilization by beef cows II. Effects of corn steep liquor (CSL) supplementation on intake and digestion of Tallgrass prairie hay contaminated with sericea lespedeza (*Lespedeza cuneata*). Proc. West. Sec. Amer. Soc. Anim. Sci. 62:203-206.

Eckerle, G. J., K. C. Olson, J. R. Jaeger, J. W. Waggoner, J. L. Davidson and L. A. Pacheco. 2011c. High-tannin forage utilization by beef cows III. Effects of corn steep liquor supplementation on voluntary selection of Tallgrass prairie hay contaminated with sericea lespedeza (*Lespedeza cuneata*) and uncontaminated Tallgrass prairie hay. Proc. West. Sec. Amer. Soc. Anim. Sci. 62:207-210.

Eckerle, G. J., K. C. Olson, J. R. Jaeger, J. L. Davidson, T. K. Kraft, and L. A. Pacheco. 2010. Effects of sun-curing and harvest maturity on concentration and protein-binding capacity of condensed tannins in sericea lespedeza (*Lespedeza cuneata*). Proc. West. Sec. Amer. Soc. Anim. Sci. 61:30-34.

Eddy, T., J. Davidson, and B. Obermeyer. 2003. Invasion dynamics and biological control prospects for Sericea lespedeza in Kansas. Great Plains Research: A Journal of Natural and Social Sciences. 13:217-230.

Jones, W. T., and J. L. Mangan. 1977. Complexes of the condensed tannins of sainfoin (*Onobrychis viciifolia* Scop.) with fraction 1 leaf protein and with submaxillary mucoprotein, and their reversal by polyethylene glycol and pH. J. Sci. Food Agric. 28:126-136.

Owensby, C. E. 1973. Modified step-point system for botanical composition and basal cover estimates. J. Range Manage. 26:302-303.

Vermeire, L. T., T. G. Bidwell, and J. Stritzke. 2007. Ecology and Management of Sericea Lespedeza. Oklahoma Cooperative Extension Service PSS-2874. Available at: http://dasnr22.dasnr22.dasnr.okstate.edu/ docushare/dsweb/Get/Rendition-759/PSS-2874web%20color.pdf. Accessed 04/05/12.

Wagner, J. J., K. S. Lusby, J. W. Oltjen, J. Rakestraw, R. P. Wettermann, 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.

Webb, D. M. 2008. Assessing the potential of mixed grazing goats with beef cattle to improve animal performance and increase the utilization of marginal pastureland in Appalachian coal region. M. S. Thesis. Virginia Polytechnic Institute and State University.

Chapter 5 -

Effects of pre-partum corn steep liquor supplementation on performance of beef cows and calves

L. A. Pacheco, E. A. Bailey, G. W. Preedy, and K. C. Olson

Abstract

The objective of our study was to evaluate the effects of pre-partum corn steep liquor supplementation on postpartum beef cow and calf performance. Angus × cows and heifers (n = 263; initial BW 470 ± 6.1 kg) grazing native range were blocked by weight, parity, and BCS and assigned randomly to 1 of 2 treatments: corn steep liquor (**CSL**; 34.4% CP) or a 40% CP mixture of soybean meal and corn (**CON**). Treatments were applied during a 60-d period that immediately preceded the earliest predicted calving date; each cow was fed the equivalent of 664 g of CP daily supplied by either CSL or CON. Supplement delivery was prorated over 3 feeding episodes weekly. Body weight and BCS of cows and BW of calves were recorded at intervals from January to August. Cow BW and BCS at the outset of the trial were similar ($P \geq 0.14$) between treatments. In contrast, cow BW and BCS were greater ($P \leq 0.04$) at calving and pre-breeding for CON-supplemented cows than for CSL-supplemented cows. At weaning, cow BW was greater ($P < 0.01$) for CON than for CSL but BCS was similar ($P = 0.11$) between treatments. Cow BW change from trial initiation to calving, from pre-breeding to weaning, and from trial initiation to weaning was more favorable ($P \leq 0.04$) for CON cows than CSL-supplemented cows. Conversely, from calving to pre-breeding CSL-supplemented cows gained more BW ($P < 0.01$) than CON cows. Cow BCS change was similar ($P \geq 0.12$) between treatments from trial initiation to calving, from pre-breeding to weaning, and from trial initiation to weaning; however, from calving to pre-breeding, CSL cows gained slightly more BCS ($P = 0.04$) than CON cows. Pregnancy to timed AI was numerically greater for CSL cows than for CON cows (52% vs. 39%, $P = 0.08$); however, pregnancy rate to AI + 1st natural service was numerically greater for CON cows than for CSL cows (76% vs. 65%, $P = 0.10$). Calf BW was not affected ($P \geq 0.44$) by dam treatment at calving or pre-breeding. In contrast, calf BW at weaning and adjusted 205- calf BW tended ($P \leq 0.08$) to be greater for calves of CON-fed cows than for calves of CSL-fed cows. Calf ADG from birth to pre-breeding was not different (P = 0.75) between treatments; however, calf ADG from pre-breeding to weaning was slightly greater (P = 0.03) for calves born to CON-fed dams than for calves born to CSL-fed dams. Birth-to-weaning ADG tended (P = 0.08) also to be greater for CON calves than for CSL calves. Under the conditions of our study, pre-partum CSL supplementation did not generally promote beef cow and calf performance that was equivalent to supplementation with an isonitrogenous amount of a dry, corn-soybean meal alternative.

Key Words: beef cows, corn steep liquor, supplementation

Introduction

Pre-partum supplementation is a vital part of beef cow nutrition in areas of the US that are faced with poor forage quality during the pre-calving period. In the Flint Hills of Kansas, stockpiling native tallgrass prairie forage for winter grazing is an effective means of providing abundant, low-cost forage for beef cows during the winter months. Stockpiled native tallgrass prairie forage can potentially supply most of the energy required by beef cows; however, CP content is generally < 5%. In order to achieve acceptable DM intake and DM digestibility, supplementation of CP is required (Clanton and Zimmerman, 1970; Pruitt et al., 1993; Beaty et al., 1994). Supplemental protein generally represents the single greatest expense of the production cycle for cow-calf producers who rely on stockpiled-forage grazing during winter in the Flint Hills region. Traditional, manufactured CP supplements can be impractical, due to rising costs of oilseed meals, processing, and energy. Therefore, alternative feeds useful for delivering supplemental CP warrant evaluation, particularly low-cost corn milling co-products such as distiller's grains, condensed corn distillers solubles, corn gluten feed and corn steep liquor. Köster et al. (1996) indicated that intake and digestion of low-quality tallgrass prairie forage by beef cows would be maximized when the feeding rate of ruminally-degradable protein averaged between 180 and 540 g / cow daily. In practice, any source of ruminally-degradable protein can be used to effectively achieve this target. Therefore, the objective of our study was to evaluate the effects of pre-partum corn steep liquor supplementation on subsequent beef cow and calf productivity.

Materials and Methods

Animals, Treatments and Diet

All procedures were approved by the Kansas State Animal Care and Use Committee (protocol no. 2650). Angus × cows and heifers (n=263; initial BW 470 ± 6.3 kg) managed at the Kansas State University Commercial Cow-Calf Unit – Manhattan were stratified by age, BCS (1 = emaciated, 9 = obese; Wagner et al., 1988), and expected calving date at the beginning of January and assigned randomly to 1 of 2 supplement-treatment groups: 1) corn steep liquor (**CSL**; 34.4% CP) or 2) a 40% CP mixture of corn and soybean meal CON; Table 5.1). Treatments were applied during the 60-d period that immediately preceded the earliest predicted calving date. Supplement feeding rates were selected to provide an average of 664 g of CP / cow daily (1.81 kg of **CON**/cow and 4.31 kg of CSL/cow, as-fed daily); feeding rates of supplements were prorated for 3 feeding episodes per week (4.22 kg of CON/cow, as-fed, at each feeding episode and 10.06 kg of CSL/cow, as-fed, at each feeding episode). Cows were stratified by treatment and assigned randomly to 1 of 7 native tallgrass prairie pastures (n = 19 or 20 cows / treatment in each pasture). Cattle were gathered from their pastures at 0700, 3 × per week and sorted into pens by treatment and fed their allotted amount of supplement. Cows were confined until supplement consumption was complete. Supplement consumption was complete within 1 h for CON-supplemented cows and within 6 h for CSL-supplemented cows at each feeding episode. Greater time allowance for supplement consumption was necessary for CSL-supplemented cows because of the large volume of feed they were required to eat at each feeding episode. Supplementation continued until each cow reached parturition. Average Julian calving date was 99 ± 1.4 d. Following parturition, cows were fed CON in their respective pastures until May 1.

Data Collection

Cow BW and BCS were evaluated and recorded at the beginning of the supplementation period, at calving, at the beginning of the ovulation-synchronization process (06/10/2012), and on the d of weaning (08/14/12). Calf BW was evaluated and recorded at birth, at the beginning of the ovulation-synchronization process, and on the d of weaning.

Estrous Synchronization and Breeding

Blood samples were collected from all cows on May 31 (21 d prior to timed AI) ; BW and BCS were measured at that time. A second blood sample was collected on June 11 (10 d prior to timed AI), at which time ovulation synchronization was initiated using the CO-Synch + CIDR protocol. A controlled internal drug-releasing insert (**CIDR**; Pfizer Animal Health, New York, NY) was inserted intravaginally and 100 μg of GnRH (2 mL Ovacyst; IVX Animal Health, St. Joseph, MO) was administered intramuscularly. The CIDR was removed on June 18 and cows were injected intramuscularly with 25 mg of $PGF_{2\alpha}$ (Prostamate, IVX Animal Health, St. Joseph, MO). Fixed-time AI (**TAI**) was initiated on June 21, 60 to 64 hours after the $PGF_{2\alpha}$ injection. Cows were inseminated by 1 of 4 technicians using semen from 1 of 6 AI sires. All AI sires were equally represented in each treatment.

Two fertile bulls were placed into each pasture 11 d after TAI (July 2) and were removed 30 d later. Short breeding exposure was made necessary by abnormally dry conditions the summer of 2012. Pregnancy diagnosis was made by transrectal ultrasonography 33 d after TAI. Cows and calves were weighed and cows were assigned a BCS 67 d after TAI. Final pregnancy rates were diagnosed on October 25 by palpation per rectum.

Statistics

Cow and calf performance were analyzed as a randomized complete block (PROC MIXED; SAS Inst. Inc., Cary, NC). The model included effects for treatment, pasture, and treatment within pasture. Treatments within individual pastures were the experimental unit. Treatment-within-pasture was used as the error term. When protected by a significant F-test ($P < 0.05$), least squares treatment means were separated using the method of Least Significant Difference.

Pregnancy rates were analyzed using logistic regression (PROC GLIMMIX; SAS Inst. Inc., Cary, NC). The model used to assess differences in timed AI pregnancy rates and AI + 1st natural-service pregnancy rates included effects for treatment, parity, technician, pasture, cycling status and all appropriate interactions. Least-squares treatment means for pregnancy rates were reported. When protected by a significant F-test ($P < 0.05$), least-squares treatment means were separated using the method of Least Significant Difference. Treatment differences in performance and pregnancy data were discussed when $P < 0.05$; trends and tendencies were discussed when $P > 0.05$ and < 0.10.

Results and Discussion

Cow and Calf Performance

Cow BW at the outset of the trial was not different ($P = 0.38$) treatments (Table 5.2). In contrast, BW of CON-supplemented cows was greater ($P \leq 0.04$) at calving, pre-breeding, and weaning than BW of CSL-supplemented cows. In addition, cow BW change from trial initiation to calving, from pre-breeding to weaning, and from trial initiation to weaning was greater ($P \leq 0.04$) for cows supplemented with CON than for cows supplemented with CSL. Conversely, CSL-supplemented cows had greater BW change than CON-supplemented cows from calving to pre-breeding, possibly indicating a compensatory response during the period immediately subsequent to supplementation. Forage quality during that period (April and May) is, typically, excellent in the Kansas Flint Hills.

Cow BCS was not different ($P = 0.14$) between treatments at the outset of the trial (5.3 and 5.2 for CON and CSL, respectively; Table 5.2). Cows supplemented with CON had greater BCS at calving and pre-breeding than cows supplemented with CSL; however, BCS was not different ($P = 0.11$) between treatments at weaning (5.9 and 5.7 for CON and CSL, respectively). Change in BCS from trial initiation to calving, from pre-breeding to weaning, and from trial initiation to weaning was not different ($P \geq 0.12$) between treatments. Cows supplemented with CSL had slightly more favorable ($P = 0.04$) BCS change than cows supplemented with CON between calving and pre-breeding (0.9 and 1.0 for CON and CSL, respectively).

Pregnancy to timed AI tended to be greater ($P = 0.08$) for CSL-supplemented cows than for CON-supplemented cows (39 and 52% for CON and CSL, respectively; Table 5.2). This effect may have been related to greater BW and BCS changes of CSL-supplemented cows than for CON-supplemented cows immediately prior to breeding. In contrast, pregnancy to timed AI + 1st natural service tended ($P = 0.10$) to be lesser for CSL-supplemented cows than for CON-supplemented cows (76 and 65% for CON and CSL, respectively). We speculated that greater BW loss during the pre-breeding-to-weaning interval of our study may have been contributed to reduced response of CSL-supplemented cows to early natural-service breeding.

Wagner et al., (1983) reported that lactating beef cows supplemented with CSL or a 29% CP control supplement performed similarly. Both treatment groups lost BW and BCS during the study (25.0 ± 2.8 kg vs. 20.8 ± 2.6 kg and 0.8 ± 0.1 vs. 0.9 ± 0.1 for CSL and control, respectively). These authors reported also that pregnancy rates were not different between lactating cows supplemented with CSL or a 29% CP control supplement.

In our study, cows supplemented with CSL generally had lesser performance than cows that were supplemented with CON. Our treatments were formulated to supply 664 g/d of CP per cow daily during the pre-partum period. Under similar conditions, Mathis et al. (1999) reported that BCS retention of cows was maximized when supplemental soybean meal was fed at a rate of 0.30% of BW/d. In their study, the recommended level of supplemental soybean meal would have supplied about 694 g/d of CP to 518 kg cows. This work suggested that the level of supplemental CP in our study was adequate to obtain acceptable performance. Furthermore, Beaty et al. (1994) reported that supplements containing at least 30% CP were adequate for BCS maintenance of beef cows grazing dormant native tallgrass prairie forage during late gestation.

A possible cause for underperformance of the CSL-supplemented cows in our study was the duration of time that they needed to be confined for supplement consumption during the pre-partum period. Under the conditions of our study, CON-supplemented cows required a maximum of 1 h to consume supplement at each feeding episode (i.e., 4.23 kg / cow, as fed, 3 × weekly). After the period of confinement, cows were then allowed to consume dormant range forage *ad libitum*. In contrast, CSL-supplemented cows required up to 6 h to consume supplement at each feeding episode (10.06 kg of CSL / cow, as-fed, 3 × weekly). In effect, CSL-supplemented cows had approximately 15 fewer h each week to forage during the pre-partum period.

Another possible cause for underperformance of the CSL-supplemented cows in our study may have been related to the composition of CSL. Hollingsworth-Jenkins et al. (1996) reported that CP in CSL was 100% ruminally degradable. Conversely, Stalker et al. (2010) reported that only 65% of the CP in CSL was ruminally degradable. Anderson et al. (2001)

reported that both ruminally-degradable and ruminally-undegradable protein sources (**RDP** and **RUP**, respectively) were adequate protein supplements for beef cows consuming low-quality forages. In addition, Alderton et al. (2000) reported that supplementing RUP in place of or with RDP had little effect on performance of primiparous beef cows. Bailey et al. (2011) suggested also that maximum performance of gestating beef cows grazing low-quality forage was achieved when RDP was supplied at 0.09% of BW/d.

In our study, RDP was supplied at approximately 0.06% of BW/d based on the ruminal degradability predictions of Stalker et al. (2010). Therefore, RDP supply may have been inadequate in our study. Hollingsworth-Jenkins et al. (1996) reported that cows supplemented with CSL had lesser performance than cows supplemented with a blend of CSL and soybean hulls. We speculate that cows supplemented with CSL could have been limited in energy, secondary to a primary deficiency of RDP, which resulted in reductions in BW and BCS that were sustained into the subsequent summer grazing season.

Calf BW at birth and pre-breeding were not affected ($P \geq 0.44$; Table 5.3) by dam treatment. Conversely, BW at weaning tended to be greater ($P = 0.08$) for calves of CON-supplemented cows than for calves of CSL-supplemented cows (172 and 165 kg for CON and CSL, respectively). Calf ADG during the birth-to-pre-breeding interval was not different ($P = 0.75$) between treatments and averaged 1.1 kg/d. In contrast, calves of CON-supplemented dams had slightly greater ($P = 0.03$) ADG during the pre-breeding-to-weaning interval and tended to have a small advantage ($P = 0.08$) in ADG from birth to weaning than calves of CSL-supplemented dams. Adjusted 205-d BW of calves suckled by CON-supplemented dams tended also to be greater ($P = 0.07$) than adjusted 205-d BW of calves suckled by CSL-supplemented dams (253 and 241 kg for CON and CSL, respectively). Wagner et al. (1983) reported that calves whose dams were supplemented CSL and a 29% CP control supplement had similar weight gains.

Implications

Under the conditions of our study, CSL did not promote pre- or post-partum cow performance that was generally equivalent to that promoted by a dry, soybean meal-based supplement when both were fed at approximately isonitrogenous rates.

Tables

Table 5.1. Nutrient composition of corn steep liquor (CSL) and corn-soybean meal (CON) supplements fed to spring-calving beef cows during the pre-partum period

Item	Control*	Corn steep liquor
Corn %	20.0	-
Soybean meal %	80.0	-
Corn steep liquor%	-	100
Composition		
Dry Matter %	89.2	45.1
Crude Protein %	40.7	34.4
Calcium %	0.3	0.1
Phosphorus %	0.6	1.9
NDF %	10.3	3.1
ADF %	4.3	2.0

* Corn steep liquor (CSL; 34.4% CP) or a 40% CP mixture of soybean meal and corn (CON). Each cow was fed the equivalent of 272 g of CP daily supplied by either CSL or CON 3 × per week. Treatments were applied during a 60-d period that immediately preceded the earliest predicted calving date.

Table 5.2. Performance and pregnancy rates of spring-calving beef cows supplemented with either corn steep liquor (CSL) or an isonitrogenous amount of a corn-soybean meal (CON) during the pre-partum period

Item	CON*	CSL*	SE	P
Cow BW† (trial initiation), kg	474	467	6.1	0.38
Cow BW‡ (calving), kg	485	461	6.0	< 0.01
Cow BW§ (pre-breeding), kg	545	527	6.3	0.04
Cow BW# (weaning), kg	540	503	6.1	< 0.01
Cow BW change (trial initiation-calving), kg	10.6	-5.4	4.94	0.01
Cow BW change (calving to pre-breeding), kg	52.8	67.0	3.12	< 0.01
Cow BW change (pre-breeding to weaning), kg	-6.4	-22.9	5.69	0.04
Cow BW change (trial initiation-weaning), kg	52.7	38.9	4.57	0.03
Cow BCS† (trial initiation)	5.3	5.2	0.06	0.14
Cow BCS‡ (calving)	4.7	4.4	0.05	< 0.01
Cow BCS§ (pre-breeding)	5.6	5.4	0.06	< 0.01
Cow BCS# (weaning)	5.9	5.7	0.07	0.11
Cow BCS change (trial initiation-calving)	-0.6	-0.8	0.06	0.12
Cow BCS change (calving to pre-breeding)	0.9	1.0	0.06	0.04
Cow BCS change (pre-breeding to weaning)	0.2	0.3	0.05	0.23
Cow BCS change (trial initiation to calving)	0.4	0.5	0.09	0.43
AI pregnancy rate, %	39.0	52.0	0.05	0.08
AI + 1st natural-service pregnancy rate, %	76.0	65.0	0.05	0.10

* Corn steep liquor (CSL; 34.4% CP) or a 40% CP mixture of soybean meal and corn (CON). Each cow was fed the equivalent of 272 g of CP daily supplied by either CSL or CON 3 × per week.

† Treatments were applied during a 60-d period that immediately preceded the earliest predicted calving date.

‡ The average Julian calving date was 99 ± 1.4 d.

§ Measured on the day ovulation synchronization procedures were initiated (06/10/2012).

\# Calves were weaned at 128 ± 16.4 d of age on 08/14/12.

Table 5.3. Performance of beef calves born to spring-calving beef cows supplemented with either corn steep liquor (CSL) or an isonitrogenous amount of a corn-soybean meal (CON) during the pre-partum period

Item	CON*	CSL*	SE	P
Calf BW† (birth)	38.0	37.5	0.53	0.44
Calf BW‡ (pre-breeding)	105.7	106.9	1.82	0.62
Calf BW§ (weaning)	172.1	165.5	2.76	0.08
ADG (birth to pre-breeding), kg	1.1	1.1	0.02	0.75
ADG (pre-breeding to weaning), kg	1.0	0.9	0.04	0.03
ADG (birth to weaning), kg	1.1	1.0	0.02	0.08
Adjusted 205-d BW, kg	253.1	240.8	4.91	0.07

* Corn steep liquor (CSL; 34.4% CP) or a 40% CP mixture of soybean meal and corn (CON). Each cow was fed the equivalent of 272 g of CP daily supplied by either CSL or CON 3 × per week. Treatments were applied during a 60-d period that immediately preceded the earliest predicted calving date.

† The average Julian calving date was 99 ± 1.4 d.

‡ Measured on the day ovulation synchronization procedures were initiated (06/10/2012).

§ Calves were weaned at 128 ± 16.4 d of age on 08/14/12.

Literature Cited

Alderton, B. W., D. L. Hixon, B. W. Hess, L. F. Woodard, D. M. Hallford, and G. E. Moss. 2000. Effects of supplemental protein type on productivity of primiparous beef cows. J. Anim. Sci. 78:3027-3035.

Anderson, L. P., J. A. Paterson, R. P. Ansotegui, M. Cecava, and W. Schmutz. 2001. The effects of degradable and undegradable intake protein on performance of lactating first-calf heifers. J. Anim. Sci. 79:2224-2232.

Bailey, E. A., E. C. Titgemeyer, R. C. Cochran, T. J. Jones, and K. C. Olson. 2011. Influence of ruminally-undegradable protein supplementation and advancing gestation on forage use and performance by beef cows consuming low-quality, warm season forage. Proc. West. Sec. Amer. Soc. Anim. Sci. 62:217-221.

Beaty, J. L., R. C. Cochran, B. A. Lintzenich, E. S. Vanzant, J. L. Morrill, R. T. Brandt, Jr., and D. E. Johnson. 1994. Effect of frequency of supplementation and protein concentration in supplements on performance and digestion characteristics of beef cattle consuming low-quality forages. J. Anim. Sci. 72:2475-2486.

Clanton, D. C., and D. R. Zimmerman. 1970. Symposium on pasture methods for maximum production of beef cattle: protein and energy requirements for female beef cattle. J. Anim. Sci. 30:122-132.

Hollingsworth-Jenkins, K. J., T. J. Klopfenstein, D. C. Adams, and J. B. Lamb. 1996. Ruminally degradable protein requirement of gestating beef cows grazing native winter Sandhills range. J. Anim. Sci. 74:1343-1348.

Köster, H. H., R. C. Cochran, E. C. Titgemeyer, E. S. Vanzant, I. Abdelgadir, and G. St-Jean. 1996. Effects of increasing degradable intake protein on intake and digestion of low-quality, tallgrass-prairie forage by beef cows. J. Anim. Sci. 74:2473-2481.

Mathis, C. P., R. C. Cochran, G. L. Stokka, J. S. Heldt, B. C. Woods, and K. C. Olson. 1999. Impacts of increasing amounts of supplemental soybean meal on intake and digestion by beef steers and performance by beef cows consuming low-quality tallgrass-prairie forage. J. Anim. Sci. 77:3156-3162.

Pruitt, R. J., M. C. Namminga, R. H. Haigh, and D. B. Young. 1993. Level of available forage and supplemental protein and energy for cows grazing winter range. SDSU Beef Report MP 93:4-7.

Stalker, A., R. Rasby, G. Erickson, C. Buckner, and T. Klopfenstein. 2010. Feeding corn milling co-products to forage-fed cattle.1st ed. Nebraska Corn Board and University of Nebraska, Lincoln, NE.

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

Wagner, J. J., K. S. Lusby, and G. W. Horn. 1983. Condensed molasses solubles, corn steep liquor, and fermented ammoniated condensed whey as protein sources for beef cattle grazing dormant native range. J. Anim. Sci. 57:542-552.

Chapter 6 - Effects of grazing system and stocking rate on beef cow and calf performance during the summer grazing season in the Kansas Flint Hills

L. A. Pacheco, N. M. Bello, B. A. Shanks, R. C. Cochran, and K. C. Olson

Abstract

Effects of grazing system (**GS**) and stocking rate (**SR**) on cow and calf performance were evaluated during a 6-yr study. Late season rest-rotation (**LSRR**) was compared with continuous (**CONT**) grazing at low, moderate, and high SR (0.35, 0.51, and 0.75 AU/ha, respectively; AU = 454 kg total cow + calf BW). Cow-calf pairs (n = 145) were assigned randomly to pastures each yr; LSRR systems consisted of 3 equally-sized paddocks. Cattle were allowed access to all paddocks from 5/1 to 7/15 and then restricted to 2 paddocks from 7/16 to 10/1 each yr. The paddock rested from 7/16 to 10/1 was rotated annually. Cows assigned to CONT remained in assigned pastures from 5/1 to 10/1 and were not rotated. Cow and calf BW were recorded on 5/1, 7/15, and 10/1 each yr and cow BCS were assigned also at those times. Cows were exposed for natural-service breeding from 5/15 to 7/15 annually; pregnancy rates were determined via rectal palpation each November. There were no differences ($P \geq 0.19$) in cow BW and BCS between GS from 5/1 to 7/15; however, CONT produced more favorable ($P < 0.01$) cow BW change and BCS change than LSRR from 7/16 to 10/1. Season-long cow BW change (5/1 to 10/1) was greater ($P < 0.01$) for CONT than for LSRR; moreover, season-long BCS change tended to be more favorable ($P = 0.07$) for CONT than for LSRR. Pregnancy rates were not different ($P = 0.19$) between GS (92.6 and 96.0% for LSRR and CONT, respectively). Calf ADG was not different ($P = 0.63$) between grazing systems from 5/1 to 7/15. In contrast, calves under CONT had greater ($P = 0.02$) ADG than calves under LSRR from 7/16 to 10/1. Season-long calf ADG was not different ($P = 0.26$) between CONT and LSRR. Cows maintained under low and moderate SR had more favorable ($P \leq 0.01$) BW change from 5/1 to 7/15 than cows maintained under high SR. Conversely, cows maintained under either low or high SR had more favorable ($P \leq 0.04$) BW change than cows maintained under moderate SR from 7/16 to 10/1. Cows maintained under low SR had greater ($P = 0.05$) season-long BW change than cows maintained under high SR; moderate SR produced an intermediate season-long BW change that was not different ($P = 0.99$) from that produced by high or low SR. Cow BCS change from 5/1 to 7/15 was more favorable ($P = 0.02$) under moderate SR than under high SR; BCS change by cows maintained under low SR was intermediate and not different ($P \geq 0.32$) from that by cows maintained under moderate or high SR. Conversely, cow BCS change from 7/16 to 10/1 was more favorable ($P = 0.01$) under high SR than under moderate SR; late-season BCS change by cows maintained under low SR was not different ($P = 0.99$) from cows maintained under high SR or moderate SR. Season-long BCS change was not different ($P = 0.50$) between SR. In addition, pregnancy rates were not different ($P = 0.55$) between SR. Calf ADG was not different ($P \geq 0.28$) between SR at any time during the grazing season. Under the conditions of our study, CONT grazing systems produced consistently better late-season cow and calf performance than LSRR grazing systems. Season-long effects of SR on animal performance were minimal; moreover, GS and SR treatments produced equivalent pregnancy rates.

Key words: beef cows, grazing systems, stocking rate

Introduction

Since the mid-19th century, the Kansas Flint Hills have been used chiefly as a grazing resource for beef cattle. Beef-cattle producers have used these remarkably-productive grasslands for stocker production during the growing season and for cow-calf production year around. With shallow limestone bedrock and native vegetation consisting primarily of native tallgrass species, it is considered a true prairie and ideal for grazing herbivores (Anderson, 1953). Rising prices for pastureland purchase or lease dictate that grazing efficiency must be maximized under prevailing seasonal, environmental, and economic constraints; moreover, sound grazing management requires balanced prioritization of both cash-flow needs and ecological stability of native grasslands (Vallentine, 1990). In the Kansas Flint Hills, the use of specialized grazing systems that provide periodic rest from grazing during the summer months may promote ecological stability when balanced with a stocking rate that supports an acceptable level of animal performance without causing undesirable shifts in native-plant composition, soil health, or water quality.

By definition, grazing systems involve application of specialized management practices (e.g. rotation, rest, or deferment) for all or part of the grazing season. These practices may affect forage availability which may, in turn, limit animal intake and performance. The likelihood that a change in forage availability will influence performance is heavily dependent upon stocking rate. Thus, it may be misleading to compare grazing systems at a single, static stocking rate (Bransby, 1989). The objective of our research was to evaluate the interactions between grazing system, stocking rate, and time on performance of cow-calf pairs grazing continuous and late season rest-rotation systems at high, moderate, and low stocking rates.

Materials and Methods

All procedures used in the care, handling, and sampling of animals in our study were approved by the Kansas State University Institutional Animal Care and Use Committee (protocol no. 2650).

A 6-yr study was conducted at the Kansas State University Range Research Unit, located northwest of Manhattan, KS. Vegetation and soils on the site were described previously by Anderson and Fly (1955). Annual precipitation from 1992-1997 was 871, 1228, 637, 989, 783, and 741 mm, respectively. The average annual precipitation during the study was 875 mm, within 5% of the long-term average for the region (Hickman et al., 2004).

Native, annually-burned, tallgrass pastures (n = 12; 31 ± 7.1 ha) were used in our study. Treatments were assigned randomly to pastures in a 2 × 3 factorial arrangement of a completely random design. Factor 1 consisted of two grazing systems (**GS**): continuous grazing (**CONT**) and late-season-rest-rotation grazing (**LSRR**). Each grazing system was evaluated at 3 stocking rates (**SR**; factor 2): low, moderate, and high (0.35, 0.51, and 0.75 AU/ha, respectively, for a 5-mo grazing season; AU= 454 kg total cow + calf body weight). Three pastures were designated for CONT (24.3 ha/pasture), 1 at each SR. Remaining 9 pastures were designated for the LSSR (33 ± 6.9 ha/pasture). These pastures were divided into 3 groups and each pasture group was subsequently managed as a single unit, 1 unit at each SR (Figure 6.1). Pasture treatment assignments were fixed for the 6-yr duration of the experiment.

Cow-calf pairs (n = 145) were stratified by parity and BCS and assigned randomly to graze pastures from 05/01 to 10/01 each yr. Cow-calf pairs grazed pastures assigned to CONT continuously from 05/01 to 10/01 annually. In LSRR-assigned pasture groups, cow-calf pairs were given access to all 3 pastures within a group from 05/01 to 07/15 annually. Subsequently, cow-calf pairs were restricted to 2 of the 3 pastures within a group from 07/16 to 10/01. The pasture afforded late-season rest was rotated annually such that, over the course of the 6-yr study, each pasture was rested twice during that latter portion of the grazing season.

Cow and calf BW were measured and cows were assigned BCS (1 = emaciated, 9 = obese; Wagner et al., 1988) on 05/01, 07/15, and 10/01 of each yr. Cow pregnancy rates were ascertained via rectal palpation in November of each yr. Performance measurements collected during the first half of the grazing season (05/01 to 07/15) and the second half of the grazing season (07/16 to 10/01) were treated as repeated measures. Season-long performance measurements (cow BW change, cow BCS change, calf ADG, and cow pregnancy percentage) were treated as single measures.

A generalized, linear, mixed model was fitted to change in cow BW, change cow BCS, and calf ADG. The linear predictor included the fixed effects of GS, SR, season interval (5/1 to 7/15 and 7/16 to 10/1) and all 2- and 3-way interactions. The model also included the random effect of yr × GS × SR, in order to recognize their respective experimental units. In addition, the random effect of cow nested within yr was fitted to the model in order to recognize repeated measures within a cow over a grazing season.

A generalized, linear, mixed model was fitted to total change (5/1 to 10/1) in cow BW, total change in cow BCS, and season-long calf ADG. The linear predictor included the fixed effects of GS, SR, and their 2-way interaction. The model also included the random effect of yr × GS × SR in order to recognize their respective experimental units.

For season-interval and seasonlong performance measures, Kenward-Roger's procedure was used to estimate degrees of freedom and for the corresponding adjustments to estimated standard errors. Model assumptions were checked using studentized residuals and they were considered to be appropriately met. The model was fitted using the GLIMMIX procedure of SAS

(Version 9.2, SAS Institute, Cary, NC), implemented using Newton-Raphson with ridging as the optimization technique. Estimated least-squares means and corresponding standard errors were reported. Relevant pairwise comparisons were conducted using Bonferroni's adjustments to avoid inflation of Type I error rate due to multiple comparisons.

A generalized, linear, mixed model was fitted to a binomial response variable consisting of number of cows pregnant in a given EU (i.e., combination of yr, SR, and GS). The linear predictor included the fixed effects of GS, SR and their 2-way interaction. The model also included the random effect of yr as a blocking factor for GS and SR combinations and the combination of yr, SR and GS to account for variability between EU.

Over-dispersion was evaluated using the maximum likelihood-based fit statistic, Pearson Chi-Square/DF. No evidence for over-dispersion was apparent. The final statistical model used for inference was fitted using residual Pseudo-Likelihood. Kenward-Roger's procedure was used to estimate degrees of freedom and for the corresponding adjustments in estimated standard errors. The model was fitted using the GLIMMIX procedure of SAS (Version 9.2, SAS Institute, Cary, NC) and implemented using Newton-Raphson with ridging as the optimization technique. Estimated least-squares means, probability of pregnancy, and corresponding standard errors were reported. Relevant pairwise comparisons were conducted using Bonferroni's adjustments to avoid inflation of Type I error rate due to multiple comparisons.

Results and Discussion

No evidence ($P \geq 0.05$) for any 3-way interactions of GS, SR, and yr on cow BW, cow BCS, or calf ADG were observed; moreover, GS and SR interactions were not significant ($P \geq 0.05$) for any of the variables tested. Conversely, GS and SR effects on cow BW change, cow

BCS change, cow pregnancy rates, and calf ADG depended ($P \leq 0.05$) on the time (i.e., early- or late-season) that animal measurements were collected.

Grazing System. Change in cow BW, change in cow BCS, and calf ADG were influenced ($P < 0.01$) by GS and time of the grazing season; therefore, GS treatment × season-interval means were presented (Table 6.1).

In general, larger changes in cow BW occurred early in the season (i.e., 5/1 to 7/15) relative to late in the season (i.e., 7/16 to 10/1) under both systems. Cow BW change was not different ($P = 0.33$) between LSRR and CONT during the early season; however, cow BW change during the late season was greater ($P < 0.01$) on CONT pastures than on LSRR pastures. Additionally, season-long cow BW change was greater ($P < 0.01$) for cows in the CONT system than in the LSRR system.

Change in cow BCS was not different ($P = 0.19$) between CONT and LSRR during the early portion of the grazing season; however, more favorable ($P < 0.01$) BCS change occurred in the CONT system than in the LSRR system during the late season. Season-long change in cow BCS tended to be greater ($P = 0.07$) in CONT than in LSRR systems. Pregnancy rates were similar ($P = 0.19$) between grazing systems (92.6% for LSRR and 96.0% for CONT).

During the early season, there was no difference ($P = 0.63$) in calf ADG between CONT and LSRR; however, calf ADG was greater ($P = 0.02$) during the latter half of the grazing season in the CONT systems than in the LSRR systems. In contrast, season-long ADG was not different ($P = 0.26$) between LSRR and CONT.

Grazing systems were developed as a means to control the frequency and severity of herbivory by grazing livestock (Heitschmidt and Walker, 1983). Rotational grazing systems were designed primarily with the intent to provide forage plants and soils with periodic rest from grazing during the growing season and, secondarily, to improve forage quality for subsequent grazing bouts. In comparison to CONT, rotational grazing systems alter the pattern of defoliation and have been proposed to improve plant-species composition and grazing-livestock productivity; however, such reports are not universal and appear to be influenced by geographical region, climate, and type of rotational system (Briske et al., 2008).

Deferred rest-rotation grazing systems evaluated in the Flint Hills have supported lesser gains by steers than CONT systems (Launchbaugh and Owensby, 1978; Owensby et al., 1973). Conversely, an 18-year study conducted on the plains of northern Texas led researchers to conclude that cow-calf performance was more desirable under a Merrill-deferred rotational GS than a CONT system (Heitschmidt et al., 1982). It should be noted that the Great Plains region of Texas generally receives lesser annual rainfall than the Kansas Flint Hills. Deferred rest-rotations systems previously evaluated provided rest from grazing early in the growing season and were subsequently used more intensively in the latter half of the grazing season. In contrast, an LSRR system takes advantage of the high-quality forage in the spring but allows a portion of the pastureland to be rested late in the grazing season.

Intensive-early stocking is a GS comparable to LSRR, in which pastures are stocked for the first half of the grazing season at 2 × the recommended season-long stocking rate and then remain ungrazed thereafter. When compared with CONT, intensive-early stocking on tallgrass rangelands resulted in comparable or greater daily gains / steer; however, total gain / head was greater for steers that grazed continuously for the entire season (Smith and Owensby, 1978; Olson et al., 1993). In an additional study conducted in the Kansas Flint Hills, Owensby and et al. (2008) reported that steer gains were superior to CONT and intensive-early stocking when steers were grazed at 1.6 × the recommended season-long stocking rate during the first half of the season and then, following removal of a portion of the cattle, remaining steers were grazed at 0.6 × the recommended season-long stocking rate for the last half of the grazing season. These results were thought to be due to greater quality late-season forage created by intensive usage early in the season.

Stocking Rate. Evidence ($P < 0.01$) was found for an interaction between SR and time of the grazing season on changes in cow BW, changes in cow BCS, and calf ADG; therefore, SR treatment × season-interval means were presented (Table 6.2).

Early in the grazing season, cow BW change under low and moderate stocking rates were not different ($P = 0.99$); however, low and moderate stocking rates supported greater ($P \leq 0.02$) cow BW change than the high stocking rate during that period. Similarly, Houston and Woodward (1966), Hughes (1974), Heitschmidt et al. (1982), Vallentine (1990), and Huston et al. (1993) all reported that cow BW change decreased as SR increased. Late in the grazing season, cows maintained under the moderate stocking rate had less favorable ($P \leq 0.04$) BW change than cows maintained under the low and high stocking rates. This is in contrast to the work of Owensby et al. (1988) and Huston et al. (1993) who reported no difference in cattle performance between low, moderate, and high SR. Late-season cow BW changes under low and high stocking rates were not different ($P = 0.99$) in our study. Conversely, season-long change in cow BW was more favorable ($P = 0.05$) under low SR than under high SR and tended to be more favorable ($P = 0.08$) than under moderate SR. The moderate stocking rate produced a season-long cow BW change that was not different ($P = 0.99$) from that produced by the high SR.

In the early season, cows maintained under moderate SR had more favorable ($P = 0.02$) BCS change than cows maintained under high SR. Cows in the low SR treatment had a BCS change that was not different ($P \geq 0.32$) from those maintained under the moderate or high SR. In contrast, Huston et al. (1993) reported no difference in BCS change among cows grazed at low, moderate or high SR in the early season.

In the late season, the high SR treatment resulted in more favorable ($P = 0.01$) cow BCS change than the moderate SR. Huston et al. (1993) reported similar findings. As with the early season, cows maintained under the low SR had intermediate BCS change that was not different ($P = 0.99$) from cows maintained under high SR and tended to be greater ($P = 0.07$) than that by cows maintained under moderate SR. Early- and late-season calf ADG were not different ($P \geq 0.28$) between SR.

Season-long BCS change was not different ($P = 0.50$) between SR; moreover, cow pregnancy rates were not different ($P = 0.55$) between SR (93.1%, 96.3%, and 93.6% for low, moderate, and high SR, respectively). Season-long calf ADG for low, moderate, and high SR were 1.17 kg, 1.20 kg, and 1.15 kg, respectively, and not different ($P \geq 0.51$) between SR. Similarly, Owensby et al. (1988) reported no difference in cattle performance when stocked at low, moderate, and high SR during short-term experiments.

Despite the importance of selecting an appropriate GS, land resources can still be under- or over-grazed if the most efficient stocking rate is not applied. Stocking rate is one of the four principles of grazing management (Vallentine 1990; Walker 1995). Bransby (1989) warned against studies with only one stocking rate, concluding that only grazing trials which include several grazing intensities per treatment can allow for the determination of economic optimum grazing intensities over a wide range of economic conditions.

Over-grazing of native pasture affects vegetative composition in addition to diet-selection habits of cattle. Over time, both changes can lead to decreased BW gain and poorer reproductive performance (Anderson, 1953). In the northern Great Plains, average daily gain of livestock decreased consistently with increased grazing pressure (Smart et al. 2010). On native tallgrass range, season-long BW gain was greatest under moderate stocking rates, as opposed to heavy or light stocking rates (Launchbaugh and Owensby, 1978). Numerous additional studies have been conducted to measure both cattle and vegetation responses under varying SR. Generally, mature cow BW gain decreased as SR increased (Houston and Woodward, 1966; Hughes, 1974; Heitschmidt et al., 1982; Vallentine, 1990; Huston et al., 1993). Relatively high SR had negative effects on calf ADG (Woolfolk and Knapp, 1949; Houston and Woodward, 1966; Hughes, 1974). Conversely, Heitschmidt et al. (1982) and Heitschmidt et al. (1990) reported no differences in calf BW gains between regionally high and moderate SR. Likewise, Owensby et al. (1988) and Huston et al. (1993) found no difference in cattle performance when stocked at low, moderate, and high SR.

Hickman et al. (2004) reported the effects of LSRR and CONT grazing at low, moderate, and high SR on plant-community composition and diversity. There were no effects of grazing system on plant diversity; however, plant species diversity was greatest at the highest SR. Gillen et al. (1998) evaluated the effects of CONT and rotational grazing systems on tallgrass prairies under moderate and high SR. They reported that GS had minimal effects on vegetation; however, total desirable vegetation declined as SR increased.

Similarly, Walker et al. (1989) evaluated cattle diet quality and found no evidence that rotational GS provided a greater-quality diet to grazing cattle than CONT GS. These authors concluded that diet quality for grazing cattle on a heavily-stocked, rotational GS was comparable to the diet quality for cattle grazed on a moderately-stocked, CONT grazing system. Other groups of researchers have concluded that cow-calf performance was greatest under a 4-pasture, 3-herd rotational GS compared to CONT, independent of SR (Kothmann et al., 1971; Heitschmidt et al., 1982).

Implications

Under the conditions of this study cow-calf performance was more generally favorable under continuous grazing than late-season rest rotation; moreover, the stocking rates that were evaluated had minimal influences on animal performance over the 6-yr duration of the experiment. We interpreted these data, along with those of Hickman et al. (2004), to suggest that productivity of cow-calf pairs and ecological health of native tallgrass rangeland in the Kansas Flint Hills may be optimal when managed under season-long, continuous grazing that targets moderate stocking rates.

Tables

Table 6.1. Effects of grazing system and time on performance of beef cows and calves grazing native tallgrass pastures in the Kansas Flint Hills

Item	Grazing Period	LSRR*	Continuous*	SE†	*P*
Cow BW Change, kg	5/1 to 7/15	67.2	64.9	2.02	0.33
	7/16 to 10/1	17.7	29.9	2.02	< 0.01
	5/1 to 10/1	84.8	94.8	2.71	< 0.01
Cow BCS Change‡	5/1 to 7/15	0.65	0.60	0.039	0.19
	7/16 to 10/1	0.08	0.26	0.039	< 0.01
	5/1 to 10/1	0.73	0.85	0.052	0.07
Pregnancy§, %	-	92.6	96.0	1.76	0.19
Calf ADG, kg	5/1 to 7/15	1.28	1.26	0.030	0.63
	7/16 to 10/1	1.04	1.14	0.030	0.02
	5/1 to 10/1	1.15	1.19	0.027	0.26

*Late season rest-rotation (LSRR) was compared with continuous (CONT) grazing annually from 5/1 to 10/1. Cow-calf pairs (n = 145) were assigned randomly to pastures each year. LSRR systems consisted of 3 equal-sized paddocks. Cattle were allowed access to all paddocks from 5/1 to 7/15 and then restricted to 2 paddocks from 7/16 to 10/1 each year. The paddock rested from 7/16 to 10/1 was rotated annually.

†Means comparisons involved multiple SEM. The largest and most conservative were reported.

‡BCS Units, Scale = 1 to 9 (1 = emaciated, 9 = obese; Wagner et al., 1988).

§Annual natural-service breeding exposure = 5/1 to 7/15. Pregnancy ascertained via rectal palpation on approximately 11/15 annually.

Table 6.2. Effects of stocking rate and time on performance of beef cows and calves grazing native tallgrass pastures in the Kansas Flint Hills

Item	Grazing Period	Low*	Moderate*	High*	SE†
Cow BW Change, kg	5/1 to 7/15	69.8[a]	67.9[a]	60.3[b]	2.39
	7/16 to 10/1	26.5[a]	18.8[b]	26.1[a]	2.39
	5/1 to 10/1	96.3[a]	86.8[a, b]	86.2[b]	3.23
Cow BCS Change‡	5/1 to 7/15	0.64[a, b]	0.69[a]	0.55[b]	0.046
	7/16 to 10/1	0.21[a, b]	0.07[b]	0.22[a]	0.046
	5/1 to 10/1	0.85	0.76	0.77	0.062
Pregnancy§, %	-	93.1	96.3	93.6	2.69
Calf ADG, kg	5/1 to 7/15	1.27	1.32	1.24	0.036
	7/16 to 10/1	1.10	1.10	1.07	0.036
	5/1 to 10/1	1.17	1.20	1.15	0.033

[a, b] Within row, means with common superscripts are not different ($P \leq 0.05$).

* Grazing at low, moderate, and high stocking rates (0.35, 0.51, and 0.75 AU/ha, respectively, for a 5-mo seasonal annually; AU = 454 kg total cow + calf BW).

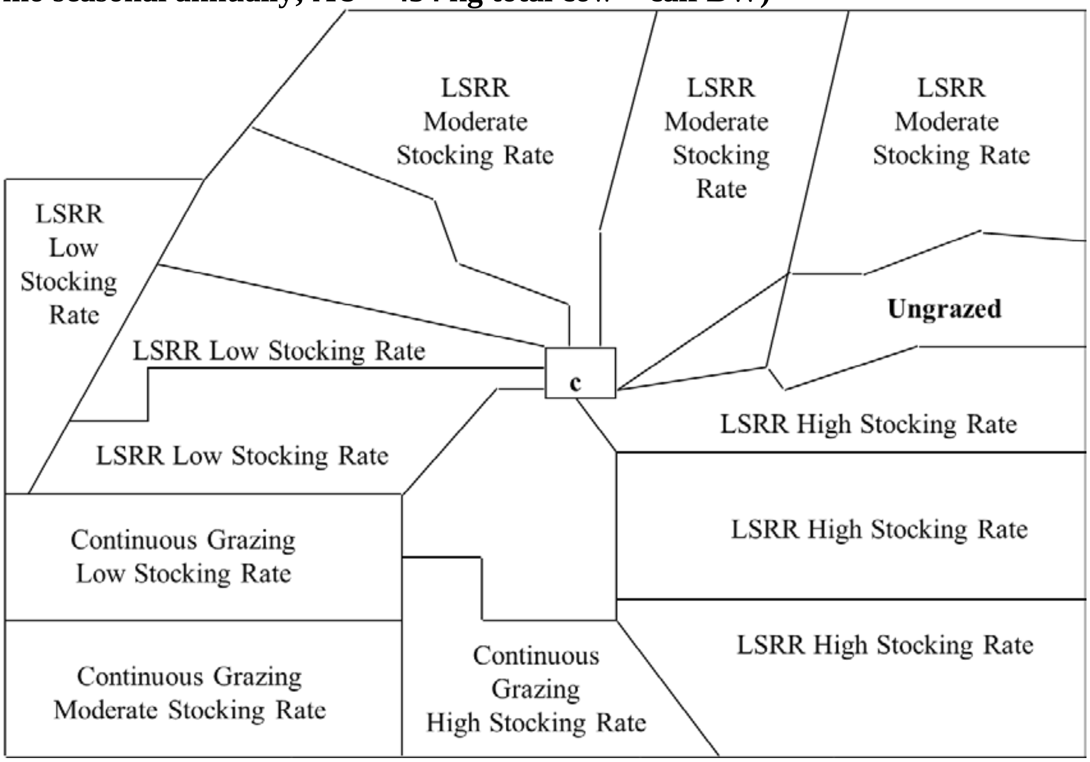
† Means comparisons involved multiple SEM. The largest and most conservative were reported.

‡ BCS Units, Scale = 1 to 9 (1 = emaciated, 9 = obese; Wagner et al., 1988).

§ Annual natural-service breeding exposure = 5/1 to 7/15. Pregnancy ascertained via rectal palpation on approximately 11/15 annually.

Figures

Figure 6.1. Schematic diagram of pasture arrangement and treatment assignments (LSRR = late-season rest rotation; stocking rates = 0.35, 0.51, and 0.75 AU/ha, respectively, for a 5-mo seasonal annually; AU = 454 kg total cow + calf BW)



Literature Cited

Anderson, K. L. 1953. Utilization of grasslands in the Flint Hills of Kansas. J. Range Manage. 6:86-93.

Anderson, K. L., and C. L. Fly.1955. Vegetation-soil relationships in Flint Hills bluestem pastures. J. Range Manage. 8:163-169.

Bransby, D. I. 1989. Justification for grazing intensity experiments: economic analysis. J. Range Manage. 42:425-430.

Briske, D. D., J. D. Derner, J. R. Brown, S. D. Fuhlendorf, W. R. Teague, K. M. Havstad, R. L. Gillen. A. J. Ash, and W. D. Willms. 2008. Rotational grazing on rangelands: reconciliation of perception and experimental evidence. Range Ecol. Manage. 61:3-17.

Gillen, R. L., F.T. McCollum, K.W. Tate, and M.E. Hodges. 1998. Tallgrass prairie response to grazing system and stocking rate. J. Range Manage. 51:139-146.

Heitschmidt, R. K., J. R. Conner, S. K. Canon, W. E. Pinchak, and J. W. Walker. 1990. Cow/calf production and economic returns from yearlong continuous, deferred rotation, and rotational grazing treatments. J. Prod. Agric. 3:92-99.

Heitschmidt, R. K., M. M. Kothmann, and W. J. Rawlins. 1982. Cow-calf response to stocking rates, grazing systems, and winter supplementation at the Texas experimental ranch. J. Range Manage. 35:204-210.

Heitschmidt, R. K., and J. W. Walker. 1983. Short-duration grazing and the savory grazing method in perspective. Rangelands 5:147-150.

Hickman, K. R., D. C. Hartnett, R. C. Cochran, and C. E. Owensby. 2004. Grazing management effects on plant species diversity in tallgrass prairie. J. Range Manage. 57:58-65.

Houston, W.R., and R. R. Woodward. 1966. Effects of stocking rates on range vegetation and beef cattle production in the Northern Great Plains. USDA Tech. Bull. No. 1357. USDA-ARS, Washington, DC.

Hughes, R. H. 1974. Management and utilization of pineland three-awn range in south Florida. J. Range Manage. 27:186-192.

Huston, J. E., P. V. Thompson, and C. A. Taylor, Jr. 1993. Combined effects of stocking rate and supplemental feeding level on adult beef cows grazing native rangeland in Texas. J. Anim. Sci. 71:3458-3465.

Kothmann, M. M., G. W. Mathis, and W. J. Waldrip. 1971. Cow-calf response to stocking rates and grazing systems on native range. J. Range Manage. 24:100-105.

Launchbaugh, J. L., and C. E. Owensby. 1978. Kansas rangelands - their management based on a half century of research. Kansas Agric. Exp. Sta. Tech. Bull. No. 622. KSRE, Manhattan, KS.

Olson, K. C., J. R. Brethour, and J. L. Launchbaugh.1993. Shortgrass range vegetation and steer growth response to intensive-early stocking. J. Range Manage. 46:127-132.

Owensby, C. E., L. M. Auen, H. F.Berns, and K. C. Dhuyvetter. 2008. Grazing systems for yearling cattle on tallgrass prairie. Rangeland Ecol. Manage. 61:204-210.

Owensby, C. E., R. Cochran, and E. F. Smith. 1988. Stocking rate effects on intensive-early stocked Flint Hills bluestem range. J. Range Manage. 41:483-487.

Owensby, C. E., E. F. Smith, and K. L. Anderson.1973. Deferred-rotation grazing with steers in the Kansas Flint Hills. J. Range Manage. 26:393-395.

Smart, A. J., J. D. Derner, J. R. Hendrickson, R. L. Gillen, B. H. Dunn, E. M. Mousel, P. S. Johnson, R. N. Gates, K. K. Sedivec, K. R. Harmoney, J. D. Volesky, and K. C. Olson. 2010. Effects of grazing pressure on efficiency of grazing on North American Great Plains rangelands. Rangeland Ecol. Manage. 63:397-406.

Smith, E. F., and C. E. Owensby.1978. Intensive-early stocking and season-long stocking of Kansas Flint Hills range. J. Range Manage. 31:14-17.

Vallentine, J. F. 1990. Grazing management. Academic Press, San Diego, CA.

Wagner, J. J., K. S. Lusby, J. W. Oltjen, J. Rakestraw, R. P. Wettemann, 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, J. 1995. Viewpoint: grazing management and research now and in the next millennium. J. Range Manage. 48:350-357.

Walker, J. W., R. K. Heitschmidt, E. A. De Moraes, M. M. Kothmann, and S. L. Dowhower. 1989. Quality and botanical composition of cattle diets under rotational and continuous grazing treatments. J. Range Manage. 42:239-242.

Woolfolk, E. J., and B. Knapp, Jr. 1949. Weight and gain of range calves as affected by rate of stocking. Montana Agric. Exp. Sta. Bull., 463. Montana State University, Bozeman, MT.