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CASE STUDY: INFLUENCE OF FALL LIQUID PROTIEN SUPPLEMENTATION ON PERFORMANCE OF BEEF COWS GRAZING NATIVE RANGE

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ABSTRACT

Improved cowherd performance has been reported form supplementing low-quality forage diets with ruminal degradable protein. Liquid protein supplements are an option of beef producers, however, the proper timing and length of the supplementation periods with liquid protein supplements is not well established. Therefore, a case study was designed to investigate liquid protein supplementation programs during late gestation. Treatments were: liquid supplementation started 60 days before weaning, liquid supplement started at weaning, and a control consisting of a hand-fed dry protein supplement started 60 days after weaning. All treatments ended with spring calving. Cows receiving liquid supplement after weaning tended ($P=0.08$) to gain body weight (BW) more rapidly and had greater ($P=0.03$) body condition score (BCS) gains than the controls. Control cows gained more BW and BCS ($P<0.01$) during the last 60 days of pregnancy. Calves from control cows gained more BW ($P<0.01$) from birth until the start of the summer grazing season and were heavier ($P<0.01$) after summer grazing. Providing a self-fed liquid supplement is a viable supplementation program in the fall to increase cow BW and BCS gains from weaning until the start of winter grazing period and it also affected subsequent calf performance.

INTRODUCTION

Profitability of beef cattle operations in the United States is highly dependent on the ability to feed cows efficiently and economically and to effectively manage the herds for high reproduction. The provision of supplemental protein at strategic times during the annual production cycle has been investigated. Llewellyn (2003) reviewed supplementation with ruminally degradable protein (RDP) of beef cattle grazing low-quality forages during the summer and fall. Although substantial quantities of literature are available with regard to summer stocker cattle (Shoop & McIlvain, 1971; Lusby et al., 1982; Grings et al., 1994), only limited literature exists focused on summer and fall supplementation of mature cows (Fleck et al., 1986; Farmer et al., 1999; Wickersham et al., 2001; Llewellyn et al., 2006). Protein supplementation strategies that take advantage of the low nutrient requirements of spring-calving beef cows during the fall have been previously studied at Kansas State University. Providing supplemental ruminally degradable protein (RDP) during this period has the potential to increase body weight (BW) and body condition scores (BCS) before winter grazing. Optimal reproductive performance and a reduction in the subsequent requirement for supplementation during the winter could be achieved by efficiently increasing BW and BCS during the fall. Farmer et al. (1999) investigated the provision of a self-fed supplement and Wickersham et al. (2001) studied the use of cooked molasses blocks during the fall for spring-calving beef cows. Later, Llewellyn et al. (2006) investigated the efficacy of providing a limited-quantity of a high-protein, hand-fed meal supplement to beef cows during the fall. Like other self-fed supplements, those in the liquid form have the benefits of reducing labor and also being continuously available.

The objectives of this study were to evaluate the effect on cowherd performance of providing a self-fed, liquid, molasses-based protein supplement to beef cows during late gestation. In addition, the time at which supplementation was initiated was investigated to determine if an advantage existed in providing the liquid supplement before vs. after weaning.

METHODS

The care and handling of animals during this experiment was conducted in accordance with the guidelines of the Institutional Animal Care and Use Committee at Kansas State University. The experimental protocols in this experiment are similar to those in a hand-fed protein supplement study from our laboratory (Llewellyn et al., 2006). One hundred twenty-two mature, pregnant, spring-calving cows and their nursing calves were assigned to supplementation treatments. The cows used in this study were primarily of Hereford X Angus breeding and their calves were sired by purebred Angus bulls. The experiment was conducted on native pastures in the Kansas Flint Hills region. The forages in the experimental pastures were a combination of both cool and warm season species, and their botanical composition was described by Owensby et al. (1993).

The cows were weighed and scored for body condition (BCS, nine point scale with average of 4 technicians' scores, 1 = emaciated and 9 = obese; Herd & Sprott, 1996). Data was collected at the beginning of the study and repeated at 60-day intervals. Calves at the cows' side were weighed at the same time as the cows until weaning. In addition, cow BW, BCS, and calf birth BW were collected within 48 h of calving (average calving date = March 17). Initial BW and BCS of the cows and BW of the calves were obtained on August 14, (cow average BW = 497 ± 46 kg; cow average BCS = 4.75 ± 0.45; calf average BW = 181 ± 19 kg), and pregnancy was confirmed by rectal palpation. Additionally, BW and BCS of the cows and calf BW measurements for the subsequent calf crop were collected at the time of movement to summer pastures to evaluate performance from birth to the start of the summer grazing period (i.e., May 2). On the days before each weighing, cows were gathered and placed in a dry lot at 14:00 h and were fed 4.5 kg of prairie grass hay per cow. All other feed and water were restricted until after weighing the next morning at 07:30 h. A mixture of salt and dicalcium phosphate (50:50) was provided during the fall, and a commercial mineral mix was provided to all cows during the winter phase (December 17 until calving).

To ensure consistent stocking rates and variability across all pastures, cow-calf pairs were stratified by BCS and pair BW and randomly assigned to one of 12 fall pasture groups based on BCS and pair weight at the start of the experiment. The 12 pasture groups were randomly assigned to three supplementation treatments with four replications. Cow-calf pairs were stocked at a consistent rate for the Kansas Flint Hills (3 ha per cow-calf pair per 6 months) as described by Owensby et al. (1995). The supplementation treatments consisted of: 1) Control; a hand-fed, high-protein, soybean meal-sorghum grain based supplement, 400 g/kg crude protein (CP), as-fed basis, provided only from December 17 until calving); 2) pre- and post-weaning supplement fed from August 14 to December 17 (QLF liquid supplement, Quality Liquid Feeds, Dodgeville, WI; 404 g/kg CP, as-fed basis; and 3) post-weaning supplement fed from weaning of the calves on October 15 to December 17 (same supplement as treatment 2). The commercial liquid protein supplement (i.e., molasses-based containing urea) was formulated to contain 660 g/kg dry matter (DM) and 53% of the N from non-protein nitrogen (NPN; DM basis) and was fed via ad libitum access to lick wheel feeder tanks as specified by the manufacturer. Before weaning, the calves had access to the liquid supplement. Estimates of intake of liquid supplement were conducted approximately every 14 d. To estimate the intake of liquid supplement by the cows, the weights of the supplement remaining in the lick wheel tanks were subtracted from the weight of the liquid supplement present in the tank at the beginning of each period and divided by number of cow days present in each pasture.

After the end of the fall supplementation period, cows were transferred to winter range on December 17. During the winter grazing period, all cows resided in three large pastures (approximately 154 ha per pasture). To ensure that all cows had resided in each of the pastures before the start of the subsequent calving season, pasture rotations occurred every 2 weeks. During the winter, provision of the liquid supplement continued for those cows that had received liquid supplement during the fall. The control cows (that received no supplement during the fall period) were hand-fed the soybean meal-sorghum based supplement that consisted of 830 g/kg soybean meal, 137 g/kg rolled sorghum grain, 30 g/kg molasses, 2 g/kg trace mineral mix, and 4,633 IU/kg Vitamin A (400 g/kg CP). The hand-fed supplement was fed at a rate to match the approximate protein intake of the liquid-fed cows. A prorated amount of the hand-fed supplement was delivered to the control cows three days per week such that they received their designated daily amount. Following calving, cows were removed from their winter grazing groups, comingled and supplementation was discontinued. After calving, all cows and newborn calves were placed in large tallgrass prairie pastures and received 5.4 kg of alfalfa hay per cow per day (as-fed basis) until movement to summer breeding range. During the winter, weather conditions and the limitation of forage availability made necessary the provision of additional brome grass hay from February 10 until April 4. Pregnancy was diagnosed via rectal palpation at the end of the summer grazing period.

Beef cow performance data were analyzed by ANOVA as a randomized complete-block design by using the GLM procedure of SAS, 2000. The 12 fall pastures were considered to be the experimental units, which provided 4 replications of the fall supplementation treatments. The LSMEANS option of SAS was utilized to determine treatment means. Treatment comparisons were made utilizing predetermined orthogonal contrasts. The FREQ procedure of SAS was used to analyze the data for pregnancy rate at the end of the breeding season.

RESULTS

Data of beef cow performance showed that the provision of a high-protein liquid supplement during the summer and fall grazing season can influence beef cow BW and BCS. Before weaning, cows that received supplementation were not different with regard to BW ($P=0.41$; Table 1) or BCS ($P=0.34$; Table 2) when compared to the cows that did not receive supplement. The BW gains of calves that were nursing fall-supplemented cows before weaning were not different ($P=0.83$; Table 3) from the gains of calves produced by the non-supplemented dams. During the post-weaning period (October 15 to December 17), the cows receiving fall supplementation tended ($P=0.08$; Table 1) to gain more BW and gained ($P=0.03$; Table 2) more BCS than the control-fed cows. During this period, the fall supplemented cows gained an average of 16 kg more BW than the non-supplemented controls. Likewise, cows that had access to the fall supplement gained 0.31 BCS more than the controls. Cumulative BW and BCS gains tended to be greater for the cows receiving fall supplementation during the entire fall period (August 14 to December 17; $P=0.13$ and $P=0.06$, respectively; Tables 1 and 2) than the control-fed cows. From the initiation of the study until the start of the calving season (February 5), no significant differences in BW or BCS changes were observed between the cows that received fall supplementation for the entire fall period compared to those cows that had their supplementation initiated following weaning. Furthermore, cumulative BW and BCS changes of the cows were not significantly affected by the time of initiation of supplementation.

Item	Treatment[a] Control	Pre+post-weaning	Post-weaning	SEM[c]	Statistical Comparisons (P-values[b]) Pre-wean vs none	Pre+post vs Post	Control vs Pre+ post and Post
No. of cows	45	39	38				
Initial BW, kg	498	496	497	5.0			
Period BW changes, kg							
Aug 14-Oct 15	42	48	36	8.6	0.41	NA	NA
Oct 15-Dec 17	18	38	30	6.8	NA	0.47	0.08
Dec 17-Feb 5	40	7	17	5.9	NA	0.28	< 0.01
Feb 5-Calving	- 63	- 75	- 69	3.6	NA	0.30	0.07
Calving-May 2	- 44	- 31	- 34	4.5	NA	0.63	0.07
Cumulative BW changes, kg							
Aug 14-Dec 17	59	86	67	8.2	NA	0.15	0.13
Aug 14-Feb 5	100	93	83	5.9	NA	0.29	0.15
Aug 14-Calving	37	18	15	6.3	NA	0.69	0.03
Dec 17-Calving	- 22	- 68	- 52	8.2	NA	0.22	< 0.01
Aug 14-May 2	- 7	- 13	- 20	5.4	NA	0.40	0.18
Calving BW, kg[d]	535	514	511	6.8	NA	0.75	0.03
May 2 BW, kg	491	483	475	5.9	NA	0.35	0.11

Table 1. Influence of fall liquid-protein supplementation on beef cow body weight (BW) changes.

[a]Treatment: Control = no fall supplementation; Pre + post-weaning = supplementation during the entire fall period; Post-weaning = supplementation beginning after calves were weaned on Oct. 15.

[b]NA = not applicable. Statistical comparison under consideration was not applicable to the designated period.

[c]SEM = standard error of the mean.

[d]Average calving date = March 17.

Item	Treatment[b] Control	Pre+post-weaning	Post-weaning	SEM[d]	Statistical Comparisons (P-values[c]) Pre-wean vs none	Pre+post vs Post	Control vs Pre+ post and Post
No. of cows	45	39	38				
Initial BCS	4.76	4.80	4.74	0.04			
Period BCS changes							
Aug 14-Oct 15	0.27	0.37	0.16	0.13	0.34	NA	NA
Oct 15-Dec 17	- 0.10	0.18	0.24	0.10	NA	0.70	0.03
Dec 17-Feb 5	0.42	- 0.12	- 0.07	0.05	NA	0.56	< 0.01
Feb 5-Calving	- 0.36	- 0.39	- 0.42	0.07	NA	0.80	0.62
Calving-May 20	- 0.14	- 0.03	- 0.07	0.05	NA	0.59	0.14
Cumulative BCS changes							
Aug 14-Dec 17	0.17	0.55	0.39	0.11	NA	0.36	0.06
Aug 14-Feb 5	0.58	0.43	0.32	0.11	NA	0.48	0.16
Aug 14- Calving	0.22	0.05	- 0.10	0.08	NA	0.23	0.03
Dec 17-Calving	0.06	- 0.50	- 0.49	0.11	NA	0.92	< 0.01
Aug 14-May 2	0.09	0.02	- 0.13	0.09	NA	0.27	0.19
Calving BCS[e]	4.98	4.84	4.64	0.08	NA	0.13	0.04
May 2 BCS	4.85	4.81	4.58	0.08	NA	0.07	0.12

Table 2. Influence of fall liquid-protein supplementation on beef cow body condition score (BCS[a]).

[a]Body condition score: 1 = emaciated; 9 = obese.

[b]Treatment: Control = no fall supplementation; Pre + post-weaning = supplementation during the entire fall period; Post-weaning = supplementation beginning after calves were weaned on Oct. 15.

[c]NA = not applicable. Statistical comparisons under consideration were not applicable to the designated period.

[d]SEM = standard error of the mean. eAverage calving date = March 17.

	Treatment[a]				Statistical Comparisons (P-values[b])		
Item	Control	Pre+post-weaning	Post-weaning	SEM[c]	Pre-wean vs none	Pre+post vs Post	Control vs Pre+post and Post
Calves on cows at beginning of study							
No. of calves	45	39	38				
Initial BW, kg	184	178	182	1.7			
Pre-weaning BW gain, kg							
Aug 14-Oct 15	67.4	68.1	67.8	1.9	0.83	NA	NA
Subsequent calf crop							
Calf birth BW, kg	41.2	38.6	42.0	0.9	NA	0.02	0.39
Calf BW on May 2, kg	90.5	78.7	85.1	1.8	NA	0.04	< 0.01
Calf BW gain, birth-May 2, kg	49.1	40.1	42.9	1.0	NA	0.09	< 0.01
Reproductive Performance							
No. of cows	43	38	35				
Cows pregnant on Oct 31[d], %	98	95	100				

Table 3. Influence of fall liquid-protein supplementation on calf body weight (BW) and beef cow reproductive performance.

[a]Treatment: Control = no fall supplementation; Pre + post-weaning = supplementation during the entire fall period; Post-weaning = supplementation beginning after calves were weaned on Oct. 15.

[b]NA = not applicable. Statistical comparisons under consideration were not applicable to the designated period.

[c]SEM = standard error of the mean.

[d]Chi-Square, P=0.36.

During winter grazing until the start of the calving season (December 17 to February 5), the control cows gained more BW and BCS (P<0.01; Tables 1 and 2) than the cows that had previously received fall supplementation. At calving, the control cows had heavier (P=0.03; Table 1) BW and greater (P=0.04; Table 2) BCS than the cows that had received fall supplementation. Therefore, the cows that did not have access to the fall supplement had the ability to compensate, at least in part, for their poorer nutritional status during the fall.

No treatment effects (P=0.39; Table 3) for fall supplementation were observed, when compared to the controls, in birth BW of the calves that were in utero during the time the cows were receiving fall supplementation. From birth until the start of summer grazing (May 2), calves nursing control dams had greater (P<0.01; Table 3) gain than calves nursing fall supplemented cows. In addition, calves produced by the control cows were heavier (P<0.01; Table 3) at the start of the summer grazing season. No significant differences were observed between the supplementation treatments with regard to pregnancy rate (Table 3). The supplement intakes are presented in Table 4.

	Intake (kg/d)[a]		
Supplementation period	Control	Pre- + post-weaning	Post-weaning
Aug 14-Oct 15	NA	2.22	NA
Oct 15-Dec 17	NA	1.42	2.08
Dec 17 to Calving	1.81	1.84	1.69

Table 4. Daily supplement intake by supplementation period of liquid and meal supplements fed to beef cows grazing tallgrass prairie range.

[a]as-fed basis

DISCUSSION

Body weight and BCS changes in the present study were in general agreement with those observed by DelCurto et al. (1990), Farmer et al. (2004) and Llewellyn et al. (2006) during both fall and winter grazing in protein supplementation investigations focusing on similar forage conditions. While no advantage to provision of the liquid supplement existed before the calves were weaned in the fall, benefits in cow performance were observed after weaning. Following weaning, the increases in BW and BCS were likely the result of increases in forage utilization as the forage quality declined with advancing vegetative maturity.

The essence of beef cow protein supplementation programs is to identify ruminal nitrogen insufficiencies and to deal with them by providing adequate RDP so that the rumen microbes will function optimally in the digestion of fibrous feeds. When grazing or feeding low quality harvested forages, protein supplementation responses are typically a result of increases in intake and digestion (Köster et al., 1996; Olson et al., 1999; Mathis et al., 2000). However, Bohnert et al. (2011) observed that intake and digestion responses of low-quality forages (i.e., those with a crude protein content of less than 65 g/kg) are dependent on forage species (i.e., cool- vs. warm-season). They noted that the provision of supplemental protein resulted in greater intake responses and digestion in the warm-season forages than the cool season forages. In addition to intake and digestion, the supplemental protein product in our study had a liquid molasses carrier that provided a readily available source of energy in the form of soluble sugars that may also have affected both BW and BCS of the beef cows.

Whenever self-fed supplements are employed, control of intake is a concern. Variations among individual cows (Sowell et al., 2003) and the social hierarchy of the cowherd (Wagnon, 1965) have been suggested as causes of unequal intakes. Supplement intakes in our study decreased by 36% after the calves were weaned (October 15) for the cows that received pre- and post-weaning liquid supplementation. Under the conditions of this experiment because it was impractical to prevent calves from consuming supplement, it is likely that this discrepancy reflects consumption of supplement by the calves and greater dry matter intake levels of the cows associated with lactation. This does not, however, explain why cows that started receiving their fall supplementation after weaning had 46% greater intakes than the pre- and post-weaning supplemented cows following removal of their calves. Supplement intake was relatively constant during the winter phase.

During the winter, significant increases in BW and BCS were observed in the control cows that had not received fall supplementation, but were provided with the hand-fed meal supplement. From December 17 to February 5, the control cows gained significantly more weight (28 kg) than the cows that had access to the fall supplement. In addition, the control cows also gained 0.52 more BCS during the same period. Each of these observations point to the resiliency of beef cows under harsh winter conditions by their ability to efficiently cycle weight and effectively use energy reserves at times when nutrient availability is low. These observations are supported by data that showed the control cows having greater BW at calving and the tendency for greater BW upon movement to summer pastures (May 2). The results for BCS of the control cows at calving and movement to summer pastures mirrored the findings for BW.

No effect on BW gains was observed for the calves nursing the cows during fall supplementation. However, greater gains (from birth until movement to summer pastures) were observed in calves in the subsequent calf crop produced by the control cows. When considered together with the tendency for the control cows to lose more BW and BCS during the same period, the calves from the control cows may have benefited from an increase in milk production at the expense of maternal reserves. These same relationships were observed in a previous fall supplementation study utilizing a hand-fed high-protein supplement (Llewellyn et al., 2006).

CONCLUSIONS

The provision of a self-fed liquid supplement to beef cows grazing poor quality forage resulted in BW and BCS gains during the period from weaning until the start of the winter grazing period. Those cows not receiving liquid protein supplementation during the fall had the ability to compensate for their earlier nutritive status during the pre-calving period when they were appropriately supplemented during the winter. Therefore, timing and duration of protein supplementation, whether it be in a liquid or a dry form, can be used to manage cow's body weight and body condition scores at strategic times in the production cycle. Furthermore, the type or duration of protein supplementation had similar effects on the subsequent calf performance and cowherd reproductive efficiency. Additional investigations into provision of a self-fed liquid supplement could be focused on young cows or on cows entering the fall in a compromised state of body condition.

LITERATURE CITED

Bohnert, D.W., DelCurto, T., Clark, A.A., Merrill, M.L., Falck, S.J., & Harmon, D.L., (2011). Protein supplementation of ruminants consuming low-quality cool- or warm-season forage: Differences in intake and digestibility. J. Anim. Sci. 89, 3707-3717.

DelCurto, T., Cochran, R.C., Corah, L.R., Beharka, A.A., Vanzant, E.S., & Johnson, D.E., (1990). Supplementation of dormant tallgrass-prairie forage: II. Performance and forage utilization characteristics in grazing beef cattle receiving supplements of different protein concentrations. J. Anim. Sci. 68, 532-542.

Farmer, C.G., Woods, B.C., Cochran, R.C., Heldt, J.S., Mathis, C.P., Olson, K.C., Titgemeyer, E.C., & Wickersham, T.A., (2004). Effect of supplementation frequency and supplemental urea level on dormant tallgrass-prairie hay intake and digestion by beef steers and prepartum performance of beef cows grazing dormant tallgrass-prairie. J Anim. Sci. 82, 884-894.

Farmer, C.G., Cochran, R.C., Simms, D.D., & Wickersham, T.A. (1999). Determining the impact of self-feeding a protein supplement during the fall on performance of beef cows grazing tallgrass-prairie range. Kansas State University. Unpublished data.

Fleck, A.T., Lusby, K.S., & McCollum, F.T., (1986). Corn gluten feed or soybean meal as summer supplements for growing beef cattle grazing native range. In: OSU Summary of Research: The Effect of High Protein Supplementation of Summer Stocker Cattle. Pp. 32-35. Okla. Agric. Exp. Sta., Stillwater, OK, USA, MP 118.

Grings, E.E., Adams, D.C., & Short, R.E., (1994). Protein supplementation of stocker cattle in the Northern Great Plains. J. Range. Manage. 47, 303-307.

Herd, D.B., & Sprott, L.R., (1996). Body condition, nutrition and reproduction of beef cows. Texas Agric. Ext. Serv. Bull. 1526, College Station, TX, USA.

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

McIlvain, E.H., (1956). Drouth management of ranges. The Shorthorn World. 41, 211-217. Llewellyn, D.A., 2003. Influence of low-level fall protein supplementation on performance and forage utilization by beef cattle grazing tallgrass prairie. M.S. Thesis. Kansas State University, Manhattan, KS, USA.

Llewellyn, D.A., Cochran, R.C., Marston, T.T., Grieger, D.M., Farmer, C.G., & Wickersham, T.A., (2006). Influence of limited fall protein supplementation on performance and forage utilization by beef cattle grazing low-quality native grass pastures. Anim. Feed Sci. Tech. 127, 234-250.

Lusby, K.S., Horn, G.W., & Dvorak, M.J., (1982). Energy vs protein supplementation of steers grazing native range in late summer and early fall. In: OSU Summary of Research: The Effect of High Protein Supplementation of Summer Stocker Cattle. Pp. 1-4. Okla. Agric. Exp. Sta., Stillwater, OK, USA, MP 112.

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

Olson, K.C., Cochran, R.C., Jones, T.J., Vanzant, E.S., Titgemeyer, E.C., & Johnson, D.E., (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., Coyne, P.I., Ham, J.M., Auen, L.M., & Knapp, A.K., (1993). Biomass production in a tallgrass prairie ecosystem exposed to ambient and elevated CO2. Ecol. Appl. 3, 644-653.

Owensby, C., Cochran, R., Anderson, K., Smith, E., & Vanzant, E., (1995). 50 Years of Range Research Revisited. Kansas State University, Manhattan, KS, USA, pp. 3-7.

SAS, (2000). SAS (Release 8.1). SAS Inst., Inc., Cary, NC, USA.

Shoop, M.C., & McIlvain, E.H., (1971). Efficiency of combining improvement practices that increase steer gains. J. Range Manage. 24, 113-116.

Sowell, B.F., Bowman, J.G.P., Grings, E.E., & MacNeil, M.D., (2003). Liquid supplement and forage intake by range beef cows. J. Anim. Sci. 81, 294-303.

Wagnon, K.A., (1965). Social dominance in range cows and its effect on supplemental feeding. California Agric. Exp. Stn. Bull. No. 819. University of California, Berkeley, CA, USA.

Wickersham, T.A., Cochran, R.C., Dhuyvetter, D.V., Grieger, D.M., & Farmer, C.G., (2001). Influence of low-level fall supplementation with a self-fed, high-protein supplement and level of winter supplementation on performance of beef cows grazing tallgrass-prairie range. In: Cattlemen's Day Report. Pp. 37-41. Kansas Agric. Exp. Sta., SRP 87. Manhattan, KS, USA.

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