ABSTRACT

Cattle (Bos sp.) weight gain on bermudagrass [Cynodon dactylon (L.) Pers.] pastures declines in the middle to late grazing season regardless of forage supply. Nutrient supplementation with concentrates is an option for boosting average daily gain (ADG), but economic feasibility of this management is not clearly understood. A grazing experiment was conducted in 1998 and 1999 with yearling steers grazing bermudagrass to evaluate ADG and costs as amounts of supplemented ground corn (Zea mays L.) (0, 0.45, 1.35, and 2.25 kg steer⁻¹ d⁻¹) increased and to monitor seasonal changes in bermudagrass in vitro digestible dry matter and crude protein (CP) concentration. There was a curvilinear increase in ADG as supplementation was increased from 0 and 1.35 kg steer⁻¹ d⁻¹, but ADG stabilized between the 1.35- and 2.25-kg rates. In vitro digestible dry matter and CP concentrations declined over the two grazing seasons, but CP concentration increased following the second application of N fertilizer in 1998 when rainfall was adequate for bermudagrass growth and N uptake. Cost of additional ADG from supplementation tended to be lowest for the 1.35 kg steer⁻¹ d⁻¹ supplementation rate over a range in corn costs from $90 to $250 Mg⁻¹. The 1.35-kg-supplementation rate provided costs of additional ADG that were lower than break-even costs for low ($1.32 kg⁻¹ liveweight), intermediate ($1.77 kg⁻¹ liveweight), and high ($2.20 kg⁻¹ liveweight) cattle prices. Costs of additional ADG for the 0.45- and 2.25-kg-supplementation rates were lower than the break-even costs for high cattle prices when corn costs were less than $170 and $190 Mg⁻¹, respectively. Supplementation with ground corn at rates of 0.45 to 1.35 kg steer⁻¹ d⁻¹ can cost effectively enhance weight gain of yearling steers grazing bermudagrass.

BERMUDAGRASS is the most widely grown warm-season perennial grass in the southeastern USA. The grass can be productive in moderately drained and fertile soils (Burton and Hanna, 1985), but forage quality of the grass has been reported to decline in the middle to late grazing season (Utley et al., 1974, 1981; Pitman et al., 1984; Aiken and Brown, 1996). Reduced cattle weight gain during this period can be partially attributed to the adverse effect of high ambient temperature and humidity on intake. Additionally, high temperatures adversely affect forage quality by increasing plant maturity and lignification (Henderson and Robinson, 1982a). Hill et al. (2001) concluded that reductions of ADG on bermudagrass pasture in the late grazing season are related to higher energy requirements for maintenance as body weights increase over the grazing season and to lower forage quality in the late season.

Lower weight gain during the summer with warm-season perennial grasses has been associated with lower organic matter digestibility (Duble et al., 1971; Pitman and Holt, 1982; Henderson and Robinson, 1982b). Aiken and Brown (1996) found in a 2-yr grazing experiment in west-central Arkansas that in vitro digestible organic matter of common bermudagrass was greater than 600 g kg⁻¹ OM in early June but declined to less than 500 g kg⁻¹ OM by the middle of July. In vitro digestibilities will vary, however, among bermudagrass cultivars (Hill et al., 2001) and are typically lower for common bermudagrass than for the hybrids. Maturity will reduce the digestibility of bermudagrass, but the decline does not appear to be directly related to increases in neutral detergent fiber (Hill et al., 1993; Mandebvu et al., 1998, 1999). Mandebvu et al. (1999) compared neutral detergent fiber and digestibilities between 'Tifton 85' and 'Coastal' bermudagrass hays. Although Tifton 85 was 5.9% higher in neutral detergent fiber, it also had in vivo digestibilities that were 9% higher for organic matter and 13.3% higher for neutral detergent fiber. It was concluded that the higher quality of Tifton 85 compared with Coastal was associated with Tifton 85 having lower concentrations of acid insoluble lignin and ether ferulic acid. Supplementation with small quantities of high-energy grains might enhance weight gains of stocker calves on bermudagrass. Goetsch et al. (1991) reported a 61% increase in ADG when feeding ground corn at 0.5% of body weight to steers grazing ryegrass (Lolium multiflorum L.) in late spring and bermudagrass in the summer. From a review of the literature, Caton and Dhuyvetter (1997) concluded that weight gain by growing cattle is often improved with energy supplementation; however, the minimum quantity of daily supplemented corn that is needed to be cost effective in increasing weight gains is not understood. A grazing study was conducted with bermudagrass to (i) evaluate steer ADG with increasing rates of daily supplemented ground corn, (ii) determine the cost of the ADG response to supplementation over a range of hypothetical corn costs and cattle markets, and (iii) monitor and assess the trends in bermudagrass CP and in vitro digestible dry matter (IVDDM) over the grazing season.

MATERIALS AND METHODS

The grazing experiment was conducted for 2 yr (1998 and 1999) at Booneville, AR, in the west-central part of the state (35°05’ N, 94°00’ W). The experimental site was on a Leadvale silt-loam soil (fine-silty, siliceous, thermic Typic Fragiudult). Dietary treatments included four levels of ground corn (0, 0.45, 1.35, and 2.25 kg steer⁻¹ d⁻¹ as-fed basis) that were

Abbreviations: ADG, average daily gain; CP, crude protein; DM, dry matter; DOP, days on pasture; IVDDM, in vitro digestible dry matter.
assigned to 1-ha pastures of bermudagrass in a randomized complete block design with three replications. The supplementation treatments were set to evaluate consumptions that are under 1% of body weight and have potential to be economically feasible. Each of the blocks contained either common bermudagrass, common and ‘Tifton 44’ bermudagrass, or common and ‘Midland’ bermudagrass. Treatments were randomized within each block in the second year.

The pastures were fertilized with split applications of N at rates of 84 kg ha⁻¹ application⁻¹. Nitrogen was applied on 13 May and 23 July in 1998 and on 28 May and 26 July in 1999. Phosphate and potash were not applied in either year because soil levels of both were above amounts recommended for maintaining productive bermudagrass.

Yearling steers of mixed breeding (0 to 50% Bos indicus) were purchased 8 to 10 wk before experimentation and grazed on mixtures of ryegrass, tall fescue ( Festuca arundinacea L.), and bermudagrass. Sixty steers at the start of the experiment were weighed shrunk by fasting from feed and water for 12 to 14 h, dewormed with ivermectin (Merek, Whitehouse, NJ), implanted with Synovex-S (Fort Dodge Animal Health, Fort Dodge, IA), and randomly assigned to the 12 bermudagrass pastures. The pastures were continuously stocked with a fixed stocking rate of 5.0 steers ha⁻¹. Grazing was initiated on 3 June 1998 with average body weights of 266 ± 4 (standard error of the mean) kg and on 9 June 1999 with average body weights of 268 ± 3 kg. Shrunken weights were taken on Day 56 and at the termination of grazing on Day 84. Steers receiving supplementation were group-fed daily between 0900 and 1000 h. A mineral and vitamin supplement that contained Ca (min. 120 g kg⁻¹, max. 140 g kg⁻¹), P (min. 120 g kg⁻¹), Na (min. 46 g kg⁻¹, max. 59 g kg⁻¹), Mg (min. 12.5 g kg⁻¹), K (min. 12.5 g kg⁻¹), Cu (min. 21 mg kg⁻¹), Se (min. 18 mg kg⁻¹), Zn (min. 300 mg kg⁻¹), Vitamin A [min. 440 000 international units (IU) kg⁻¹], Vitamin D₃ (99 000 IU kg⁻¹), and Vitamin E (33 IU kg⁻¹) was offered free-choice to all pastures.

Forage samples were collected at 2-wk intervals to determine forage mass and nutritive value. Forage was clipped at a 2.5-cm height from three randomly placed 0.25-m² quadrats each supplementation rate and corn cost combination to determine the maximum corn cost to obtain a cost of additional gain that was significantly lower (P < 0.05) than break-even costs that were set to represent low [$1.32 kg⁻¹ body weight], intermediate [$1.77 kg⁻¹ body weight] and high [$2.20 kg⁻¹ body weight] cattle prices.

Fig. 1. Relationships of in vitro digestible dry matter (IVDDM) and crude protein (CPC) concentration with days on pasture (DOP) for bermudagrass grazed in 1998 and 1999. DM, dry matter.

Herbage Mass and Nutritive Values

Herbage mass averaged 2625 ± 98 kg ha⁻¹ dry matter (DM) over the 2 yr and was not influenced (P > 0.10) by either corn supplementation rate or year. The stocking rate used in this study was chosen because it would likely provide a moderate to light grazing pressure and maximize the ability of the steers to selectively graze (Duble et al., 1971; Guerrero et al., 1984). Therefore, grazing pressure in this study was likely low enough to result in herbage mass having minimal effect on steer performance.

The IVDDM was initially high (>600 g kg⁻¹ DM) in both years and, as expected, not influenced (P > 0.05) by the corn supplementation treatments (Fig. 1). There was a curvilinear decrease in IVDDM over DOP, but the trends were not similar between the 2 yr. The IVDDM gradually declined in both years and stabilized from the no-supplement control. Cost of additional gain was analyzed using PROC TTEST of SAS (SAS Inst., 1990) for each supplementation rate and corn cost combination to determine the maximum corn cost to obtain a cost of additional ADG that was significantly lower (P < 0.05) than break-even costs that were set to represent low [$1.32 kg⁻¹ body weight ($0.60 lb⁻¹ body weight)], intermediate [$1.77 kg⁻¹ body weight ($0.80 lb⁻¹ body weight)], and high [$2.20 kg⁻¹ body weight ($1.00 lb⁻¹ body weight)] cattle prices.

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Fig. 2. Precipitation at the experimental site in 1998 and 1999, and a 43-yr average. Data were collected approximately 1 km from the site.

Fig. 3. Relationships between average daily gain (ADG) and daily supplementation rate for ground corn (CS) fed to steers grazing bermudagrass. MSE, mean square error.

Average Daily Gain

Steer ADG was exceptionally high in both years. Studies have typically reported ADG on bermudagrass to fall below 0.7 kg d\(^{-1}\) (Utley et al., 1974, 1981; Hill et al., 1993, 2001; Aiken and Brown, 1996), but ADG in the present study for the zero supplementation rate averaged 0.84 kg d\(^{-1}\) (Fig. 3). Higher ADG could be partly attributed to the presence of small concentrations of crabgrass \([Digitaria sanguinalis (L.) Scop.]\) and dallisgrass \((Paspalum dilatatum Poir.)\) in the pastures that were visually estimated to range from being negligible to approximately 20%. The quality of these grasses is generally regarded as being higher than that of bermudagrass (Ball et al., 1996). Another explanation for higher weight gains is the implantation of steers with anabolic agents. A preliminary study (Aiken, 2001) with steers grazing bermudagrass and consuming 2.25 kg corn d\(^{-1}\) showed a 20% increase in ADG by implanting with the same estradiol agent that was used in the present study. Studies evaluating estradiol implants have reported increases of 20% (Rumsey, 1978) and 30% (Kahl et al., 1978) in daily weight gain with implantation of steers on high-concentrate diets. Implantation of steers grazing native range in north-central Nebraska has resulted in 9% higher ADG than without implantation (Mader et al., 1994). A benefit of implanting pastured growing cattle with anabolic agents is apparent from research results; however, the magnitude of the weight gain response likely depends on pasture quality and forage mass.

Average daily gain for the present study was similar \((P > 0.10)\) between the 2 yr, and a year × supplementation rate interaction was not detected \((P > 0.10)\). There was a strong curvilinear increase in ADG with increased levels of supplemented corn (Fig. 3). Steer performance consistently increased between the 0 and 1.35 kg steer\(^{-1}\) d\(^{-1}\) rates but stabilized between the 1.35- and 2.25-kg rates. In a similar study with ryegrass, Sanson and Coombs (2000) reported ADG of yearling steers to in-
crease as rate of daily corn supplementation increased from 0.0 to 0.4% of body weight but was similar as supplementation rate increased from 0.4 to 0.8% of body weight. The response, however, was inconsistent over two grazing seasons.

Higher consumption of soluble carbohydrate with the 2.25-kg rate in the present study could have adversely affected forage intake, fiber digestion, or both. Higher herbage mass resulting from lower intake was not shown for the 2.25-kg rate; however, it is doubtful that herbage mass measures taken with the disk meter were precise enough to detect any subtle effects the supplementation treatments would have on intake. Pordomingo et al. (1991) showed daily corn consumption of 0.4 to 0.6% of body weight to reduce in situ digestibility and organic matter intake of warm-season forage. A negative relationship between level of corn supplementation and forage intake has been demonstrated by Chase and Hibbard (1987) with low-quality forage and by Sanson et al. (1990) with grazed native range. In their review, Caton and Dhuyvetter (1997) found reductions in forage intake and digestibility with corn supplementation being attributed to depressions in ruminal pH that cause shifts toward lower cellulolytic microbial populations. Although low amounts of corn supplementation can reduce intake and digestibility, these reductions apparently are compensated for by an increase in energy efficiency with addition of starch in the diet. This probably occurred in the present study with the observed increases of ADG as rate of corn supplementation increased from 0 to 1.35 kg steer⁻¹ d⁻¹. Lack of an additional effect with 2.25 kg steer⁻¹ d⁻¹ suggests that a threshold was reached beyond which the increase in energy efficiency with this level of starch consumption was not enough to overcome the extent that bermudagrass intake and digestibility was reduced.

Diets over the treatments were not isonitrogenous; therefore, it cannot be concluded that the response to corn supplementation resulted entirely from energy. The experiment was developed to evaluate corn as an alternative to more expensive protein supplements. Assuming that IVDDM will approximate total digestible nutrients (TDN), which is closely associated with digestible energy (1 kg TDN = 18.4 MJ digestible energy; NRC, 1996), then trends in IVDDM and CP over the grazing season suggest that energy limits weight gain more than CP. This is contradicted, however, by work by Ellis et al. (1999) that showed a strong steer ADG response on bermudagrass when supplemented with protein and the ionophore monensin. Treatment levels of 207 and 334 g d⁻¹ supplemented protein provided additional gains of 0.13 and 0.22 kg d⁻¹, respectively, over those achieved by a no-supplement control. Addition of monensin to the diets further increased the responses 92% for the 207 g d⁻¹ rate and 41% for the 334 g d⁻¹ rate. In another study with steers and heifers on bermudagrass pasture, Grigsby et al. (1989) reported that a protein supplement containing fishmeal and monensin produced a 0.35 kg d⁻¹ increase in ADG over the pasture-only control. Seasonal trends in IVDDM and CP indicate that responses to supplements can be achieved with either high energy or protein concentrates, but it is not clearly understood which will provide the most cost-effective increases in weight gain.

**Economic Analysis**

Trends in costs of additional ADG were numerically lowest over the full range of corn costs for the 1.35 kg steer⁻¹ supplementation rate, followed in order by the 0.45- and 2.25-kg rates (Fig. 4). Cost of additional ADG for the 0.45-kg supplementation rate and selling with either high or intermediate cattle prices was below the break-even cost for corn costs that were intermediate in the range of evaluated corn costs (≤$170 Mg⁻¹), indicating that a net return can be achieved with average corn costs. The 0.45-kg supplementation rate with low cattle prices showed that low corn costs (≤$100 Mg⁻¹) were needed to generate additional ADG below the break-even cost. The ADG response to this supplementation rate apparently was not enough to produce consistent returns over a wide range of possible corn and cattle market scenarios.

The 2.25-kg supplementation rate had costs of additional ADG below the break-even at an intermediate corn cost (≤$150 Mg⁻¹) for the intermediate cattle market and relatively high corn costs (≤$190 Mg⁻¹) for the high cattle market. This rate was therefore cost effective with average to relatively high corn costs combined with intermediate or high cattle prices; however, none of the evaluated corn costs with the low cattle market provided costs of additional ADG that were below the break-even. Although a return appeared possible for this rate with intermediate and high cattle markets, as previously
discussed, it was less efficient than the 1.35-kg rate because a higher quantity of ground corn was fed to obtain a similar ADG response.

Costs of additional ADG for the 1.35-kg supplementation rate were lower than the break-even within the full range of corn costs for each cattle market. Therefore, the ADG response to the supplementation rate was high enough to indicate cost-effective weight gain over a wide range of corn and cattle market scenarios. Net return per steer from the additional ADG (gross return minus cost of corn) for the $90 Mg⁻¹ corn cost was $27.34 steer⁻¹ with the low cattle price, $39.92 steer⁻¹ for the intermediate cattle price, and $52.36 steer⁻¹ for the high cattle price. Net return for a corn cost of $250 Mg⁻¹ was $8.84 steer⁻¹ with the low cattle price, $21.42 steer⁻¹ for the intermediate cattle price, and $33.86 steer⁻¹ for the high cattle price. A return was therefore estimated for all scenarios even though the return for the highest corn cost combined with the lowest cattle market was somewhat negligible.

An average of corn markets (Fort Worth, TX, ingredient market; Anonymous, 1998, 1999) for May through September in 1998 ($118.76 Mg⁻¹) and 1999 ($106.60 Mg⁻¹) showed that costs of additional ADG in both years for the 0.45- and 2.25-kg supplementation rates were below the break-even with intermediate and high cattle markets. Costs of additional ADG for both supplementation rates were above the break even with low cattle prices. The 1.35-kg supplementation rate resulted in costs of additional ADG that were considerably below the break even for the three cattle prices and, therefore, expressed the most stability over the full range of corn costs for each cattle market.

CONCLUSIONS

Results of the study show that bermudagrass IVDMD and CP will decline over the grazing season but ADG of stocker cattle grazed under moderate to light grazing pressures can respond to supplementation with ground corn in quantities between 0.45 and 1.35 kg calf⁻¹ d⁻¹. Feeding levels above 1.35 kg calf⁻¹ d⁻¹ did not provide additional increases in ADG. Cost effectiveness of supplementing with ground corn was sensitive to both cattle and corn markets. Daily feeding of 1.35 kg steer⁻¹ ground corn had the lowest costs per additional ADG over a wide range of corn costs and cattle prices. The 0.45- and 2.25-kg supplementation rates should be avoided with low cattle prices and with intermediate and high cattle prices if corn costs are high. The 2.25-kg supplementation rate was further shown impractical because the ADG response was similar to that of the 1.35-kg rate. Supplementing stocker calves on bermudagrass with 0.45 to 1.35 kg calf⁻¹ ground corn is a feasible option for boosting ADG and overcoming the summer slump in forage quality.

ACKNOWLEDGMENTS

The author expresses sincere appreciation to Mr. Samuel F. Tabler (USDA-ARS) for his valuable advice and technical support and to Ms. Tammy Y. Horton (USDA-ARS) for performing laboratory analyses. Gratitude is also extended to Dr. Ron McNew of the Agriculture Statistics Laboratory at the University of Arkansas for his advice on the statistical analysis of economic data.

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