Factors Limiting Liveweight Gain of Beef Cattle on Rangeland in Botswana

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Highlight: Six range parameters measured monthly over an 11-month period on nine ranches distributed throughout the main ecological zones of Botswana were related to the monthly liveweight changes of growing cattle. Clipped and esophageal fistula samples provided estimates of crude protein content (CP) and dry matter digestibility (DM), while available DM and grazing index provided estimates of available herbage. Linear, quadratic, and multiple regressions all indicated that liveweight change was influenced primarily by the CP content of the herbage selected. The CP content of fistula samples accounted for 54% of the variation in liveweight gain, while digestibility of the same samples accounted for 32%. Quadratic regressions failed to account for any more variance than linear regressions. The inclusion of digestibility with CP content in a multiple linear regression failed to have any effect. The addition of grazing index to CP content increased the variance accounted for in both the fistula and clipped samples from 54% to 56% and 48% to 53%, respectively. It appears that under the natural range conditions of Botswana, crude protein is presently the major limiting factor, and initial research efforts must be directed towards increasing the CP content of the diet available to beef cattle.

Botswana is an elevated plateau situated between 17° and 27° south and 20° and 30° east, covering 572,000 km² at a mean altitude of 1,000 m. Natural grasslands cover approximately 450,000 km² and support a population of 3 million cattle, and 1.5 million goats and sheep. The population of game animals is unknown but is probably several million head.

The composition of the natural grasslands varies considerably throughout the country largely due to highly variable rainfall. The extreme northeast receives a mean rainfall of 700 mm, which drops to 500 mm in the east and decreases progressively towards the west, while less than 300 mm is received in the southwest. Annual rainfall can fluctuate from less than half to twice the annual mean, while in the west some years are completely without rain. The rains occur normally between October and April.

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Under these adverse climate conditions, efficient pasture management and utilization is difficult. Results of completed work have been comprehensively reviewed by McKay (1968). Much of this earlier work was conducted on two sites only and, therefore, is not representative of all the ecosystems in Botswana.

The importance of cattle production in Botswana cannot be over emphasized. It is the country's main foreign currency earner and will remain so for many years. In 1975 cattle exports realized S.A. R40 million (BMC Annual Report 1975).

The objectives of the work described in this paper were to evaluate the usefulness of different range parameters for establishing limiting factors in animal production, and to indicate future lines of research in a more rational manner. An initial survey was conducted to determine the questions that needed to be answered rather than to provide any answers.

Materials and Methods

The investigations were conducted on nine beef cattle stations, situated in differing ecological zones, from October 1972 to August 1973. Several measurements were made at monthly intervals at each station. Rainfall (mm) was determined with standard rain gauges. Monthly estimates of available herbage dry matter (ADM) were made from fifteen 1-m² quadrats randomly distributed throughout the grazed paddocks and harvested to ground level. ADM is a simple estimate of dry matter available per unit area. Grazing index (GI) was calculated to account for station variations in ADM per unit area, paddock size, number of animals, and mean weight of the animals. GI was felt to be an improved alternative to stocking rate as an estimate of grazing

Table 1. The total rainfall (mm) for each station from October 1972 to August 1973 and the 5-year mean.

Station	5-Year mean 1970-75	Year of trial Oct. 1, 1972-Aug. 1973
Masama	536	240
Impala	504	213
Good Hope	592	291
Boswelatlou	619	444
Musi	580	313
Masiatilodi	511	360
Matlolakgang	432	250
Tsetseku	444	109
Sunnyside	612	319
Mean	537	282

Table 2. Means and standard deviations (S.D.) for the variables included in the study.

Variable	Whole year (Oct.–Aug.)		Wet season (Oct.–Apr.)		Dry season (May–Aug.)	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Liveweight gain (kg/month)	10.0	10.86	14.5	9.48	2.1	7.75
Crude protein (%)						
a) of clipped	4.7	1.77	5.2	1.93	3.7	.65
b) of fistula	8.5	2.79	9.6	2.68	6.5	4.37
Dig. of dry matter						
a) of clipped	34.7	5.37	36.0	5.88	32.5	2.78
b) of fistula	41.3	5.61	42.9	5.87	38.4	3.62
Quantity						
a) Grazing index (kg DM/kg liveweight)	19.1	7.64	22.0	6.05	13.9	3.40
b) Available dry matter (kg/ha)	1150	107.30	1168	289.35	1118	252.26

pressure. This was constructed as kilograms of dry matter available per kilogram of animal liveweight from the following formula:

$$\text{Grazing Index} = \frac{(\text{Kg ADM/ha}) \times \text{No. of ha}}{(\text{No. of animals}) \times \text{Mean wt. of animals}}$$

Crude protein (CP) content of the same clipped samples was determined using the Kjeldahl method. In vitro digestibility of DM of the same clipped and fistula samples were determined using the method of Tilley and Terry (1963) as modified by Minson and McLeod (1972). CP content of esophageal fistula samples was also determined. These were collected on two consecutive days from three fistulated steers grazing with the animals whose performance was being recorded. Monthly liveweight gains of cattle born between October 1971 and January 1972 and weaned by July 1972 were also determined. The average group size was 80 animals with a mean age of 10 months and mean weight of 187 kg at the start of the trial. All cattle were allowed access to a bonemeal and salt mixture throughout the study, as previous work had shown the benefits of such a practice (APRU 1971). The cattle were also allowed 24-hour access to grazing and water.

Results

The period was much drier than usual with many stations receiving less than half the normal rainfall (Table 1). Note that rainfall amounts in the second column are only for 11 months as the rains came early in September. Since the important fact is

Table 3. The linear regression coefficients of the independent variables on monthly liveweight change and the coefficients of determination for the whole year, the wet season, and the dry season.

Variable y=LVG (kg/month)	Whole year		Wet season		Dry season	
	b	r ²	b	r ²	b	r ²
x ₁ =CP % clipped	4.27**	0.48**	3.04**	0.38**	6.91**	0.34**
x ₂ =CP % fistula	2.87**	0.54**	2.25**	0.41**	2.63**	0.25**
x ₃ =Dig. clipped	1.04**	0.26**	0.76**	0.22**	0.83	0.09
x ₄ =Dig. fistula	1.09**	0.32**	0.83**	0.26**	0.55	0.07
x ₅ =Grazing index (kg DM/kg liveweight)	0.33**	0.05*	0.39	0.06	0.84*	0.14*
x ₆ =Available DM (kg/month)	0.0005	0.0003	0.0003	0.0001	0.008	0.07

* Significant at *P* 0.05.

** Significant at *P* 0.01.

the rainfall occurring in one growing season, it would be wrong to include the September rainfall here, because it begins a second season.

There was a positive relationship between CP content, digestibility, and liveweight gain but no apparent relationship between liveweight gain and available dry matter or grazing index (Fig. 1).

There was considerable variation in each parameter throughout the year and from ranch to ranch (Table 2). The greatest amount of variation in liveweight change (54%) was accounted for by CP content of the fistula sample, followed by CP content of the clipped sample (48%) (Table 3). The two digestibility measurements accounted for only 32% and 26%, respectively, of the variation in liveweight change. Relative to digestibility, crude protein was more important in both the wet and the dry season. However, the effect of digestibility was much greater in the wet season than in the dry. While digestibility of the fistula and clipped samples accounted for 26% and 22%, respectively, of the total variance in the wet season, they accounted for only 9% and 7% in the dry season.

Quadratic regressions failed to account for any more of the variation in liveweight gain than did linear regressions and are consequently not reported here.

Multiple linear regression analyses using two and then three independent variables were calculated (Table 4). In every case one variable was used from each of the groups representing alternative methods of describing the herbage.

Table 4. Multiple linear regression analyses on two and three independent variables on monthly liveweight change and the coefficients of determination for the whole year, the wet season and the dry season.

Independent variables	Whole year				Wet season				Dry season			
	b ₁ ⁷	b ₂	b ₃	r ²	b ₁	b ₂	b ₃	r ²	b ₁	b ₂	b ₃	r ²
CPC ¹ + DC ²	4.39	-.05	—	.48	3.06	-.008	—	.38	6.48	.28	—	.35
CPC + GI ³	4.23	.31**	—	.53	3.05	.005	—	.38	6.17	.34	—	.36
CPC + ADM ⁴	4.31	.002	—	.49	3.07	-.002	—	.39	6.56	.004	—	.35
CPF ⁵ + DF ⁶	2.83	.02	—	.54	1.99	.15	—	.41	3.11	-.29	—	.26
CPF + GI	2.79	.17	—	.56	2.34	.09	—	.41	2.20	.40	—	.27
CPF + ADM	2.87	.001	—	.54	2.29	.003	—	.41	2.45	.003	—	.25
CPC + DC + GI	4.40	-.07	.31*	.53	3.07	-.009	.005	.38	5.92	.21	.30	.36
CPC + DC + ADM	4.48	-.08	.002	.49	3.15	-.03	-.002	.39	6.22	.24	.003	.36
CPF + DF + GI	2.75	.03	.17	.56	2.07	.18	.11	.41	2.72	-.33	.42	.28
CPF + DF + ADM	2.83	.02	.001	.54	2.06	.14	.003	.42	3.03	-.39	.004	.27
CPC + GI + ADM	4.24	.30*	.001	.53	3.20	.09	-.003	.39	6.16	.26	.002	.36
CPF + GI + ADM	2.79	.18	.0	.56	2.31	.02	.002	.41	2.24	.48	-.002	.27

¹ CPC = Crude protein, clipped sample.

² DC = Digestibility, clipped sample.

³ GI = Grazing index.

⁴ ADM = Available dry matter

⁵ CPF = Crude protein, fistula sample.

⁶ DF = Digestibility, fistula sample.

⁷ In Table 4, all b₁ values and all r² values are significant at *P*<0.01.

** Significant at *P*<0.01.

* Significant at *P*<0.05.

Fig. 3. Summary of results from nine stations illustrating the relationship of each parameter measured to liveweight change.

The inclusion of digestibility to CP content as a second independent variable did not account for any more variance compared with CP content used alone in a linear regression. However, the addition of GI to CP content of the clipped sample accounted for 53% of the variance for the whole year compared to 48% when CP content of the clipped sample was used alone.

The addition of GI to CP percentage from the fistula sample increased the variance accounted for from 54% to 56%.

The two quantity measurements, ADM and GI, were then both included in a regression analysis with CP content. This was done as GI and ADM need not be related. However, no additional variance was accounted for with this combination.

Discussion

The levels of CP content under which this trial was conducted were low compared with those of temperate conditions. The mean for the year from esophageal fistula samples was 8.5%, rising from a mean of 5.7% in the dry season to a mean of 9.4% in the wet part of the year. Under these conditions it would appear that CP content is more important in limiting weight gain of cattle in this region than is digestibility.

As digestibility accounted for more variation in weight gain during the wet season than in the dry season, it would indicate that as CP content becomes less of a limiting factor, digestibility has more influence on cattle weight change.

As quadratic regressions failed to account for any more variance than linear regressions, further substantial increases in live weight gain could be expected if CP and digestibility of the herbage could be increased.

The inferences of the CP content and digestibility data are in disagreement with workers in temperate climates (Hodgson 1968; Rodriguez and Hodgson 1974), who found that energy is the major limiting factor, but are in agreement with many workers in the tropics and subtropics (Topps 1962; Van Niekerk 1974). Van Niekerk, in a recent review of work under similar conditions in South Africa, states that the feeding of energy-rich but protein deficient foods gives poor responses in animal production and depresses forage intake. He concludes that energy is not the first limiting factor in these dry grasslands.

The increased amount of variance accounted for by the fistula samples compared with the clipped forages was rather small. In many areas of Botswana, the use of fistulated steers is not possible, but the results indicate that combining data from clipped samples and grazing index represents an index of opportunity for selection and gives a reasonable measure of quality, which accounts for as much variance as fistula samples.

As CP content has been shown to be a major limiting factor to growth of beef cattle, the feeding of nonprotein nitrogen licks is indicated as a possible method of overcoming this problem.

Results of these trials are reported by Capper et al. (1976).

Another approach is to encourage grasses having above-average levels of CP. Since April 1974, 30 different species of grass have been collected monthly and screened for CP content and digestibility. The results to date (APRU 1976) indicate that certain species are superior in CP content and digestibility. Large scale grazing trials have now been initiated in an attempt to encourage the better species and to determine if improved cattle performance results. A further approach has been to remove the bush cover and monitor the improvement or otherwise in the species composition.

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