

Protein, energy and phosphorus supplementation of cattle fed low-quality forage

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The effect of protein, energy and phosphorus supplements, fed individually or in various combinations, on roughage intake and livemass change was measured in a $2 \times 2 \times 2$ factorial arrangement of treatments. The experiment was conducted under controlled conditions designed to simulate conditions which exist in practice when animals are fed supplementary licks on winter grassveld. The level of supplementary feeding was designed to supply 60%, 10% and 50%, respectively, of the animals' daily requirements for protein, energy and phosphorus in the form of the supplement only. Protein supplementation, averaged for all treatments, increased roughage intake 34.5% over the non-supplemented groups. Protein-supplemented cattle also lost only 4.7 kg livemass whereas the groups not receiving protein lost an average of 19.6 kg. In marked contrast to protein, low-level energy supplementation had an insignificant, small positive effect on both feed intake and livemass change except where it was given as the only supplement and where it had a negative effect on animal performance. Phosphorus supplementation, except where it was given in combination with both protein and energy, tended to have a negative effect on both feed intake and livemass change. The response to protein was only slightly enhanced by combining protein lick with both energy and phosphorus supplements. This experiment shows that a protein deficiency is by far the most important cause of winter mass loss in cattle maintained on low-quality forages.

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Die invloed van proteïen-, energie- en fosforaanvullings, alleen of in verskillende kombinasies, op ruvoerinname en liggaamsmassa, is met behulp van 'n $2 \times 2 \times 2$ -faktorale-rangskikking van behandelings bepaal. Die proef is uitgevoer onder gekontroleerde toestande, met die doel om die praktyk, waar diere op veldgras met lekkie oorwinter word, na te boots. Die peil van aanvullende voeding is sodanig beplan dat daar, onderskeidelik, ongeveer 60%, 10% en 50% van die diere se proteïen-, energie- en fosforbehoefes deur middel van die lekaanvulling alleen voorsien sou word. Proteïenaanvulling het die gemiddelde ruvoerinname met 34,5% bo die onaangevulde kontrolegroepe verbeter. Beeste wat proteïenaanvulling ontvang het, het slegs 4,7 kg in massa verloor terwyl die groepe wat nie proteïen ontvang het nie 19,6 kg liggaamsmassa verloor het. In teenstelling hiermee het laevlakenergie-aanvulling ruvoerinname en liggaamsmassa slegs tot 'n geringe mate bevoordeel behalwe waar dit alleen aangevul was en dan 'n negatiewe uitwerking getoon het. Fosforaanvulling, behalwe waar dit met beide proteïen en energie gesamentlik gevoer is, het 'n onderdrukkende invloed op ruvoerinname en liggaamsmassa gehad. Die reaksie wat met proteïenaanvulling verkry is, is slegs in 'n geringe mate verbeter deur die proteïenlek met energie en fosfor aan te vul. Hierdie proef toon dat 'n gebrek aan proteïen verreweg die vernaamste faktor is wat ly tot massaverliese waar diere op laegraadse ruvoere oorwinter word.

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Introduction

During the dry winter season cattle and sheep grazing the extensive grassland and savanna regions of southern Africa are unable to maintain their condition and rate of production. Unsupplemented animals will lose 25–30% of their maximum summer bodymass and the consequences are a considerable lowering of reproductive rate and reduced animal performance (Pieterse, 1966; Topps, 1971; Van Niekerk, 1974). Early studies, in which extensive surveys were conducted, showed a marked drop in protein content and in the level of most mineral elements whereas fibre levels increased during the dry season (du Toit, Louw & Malan, 1940; van Wyk, Oosthuizen & Meyer, 1955). Subsequent supplementary feeding experiments showed that protein is undoubtedly the primary limiting nutrient under these conditions and that the consequent reduction in appetite results in a secondary energy deficiency (Pieterse, 1966; Topps, 1971; van Niekerk, 1974). Energy supplements, given in isolation, have generally failed to elicit any significant positive response (Hoflund, Quin & Clark, 1948; Clark & Quin, 1951; Bishop, 1959; Verbeek & Von la Chevallerie, 1959; Stubbs, Vosloo & Coetzee, 1963). Mineral supplements, and phosphorus in particular, have also been extensively investigated. Although phosphorus supplements have been found to increase animal performance during periods when animals are gaining in bodymass, phosphorus appears to have no advantage in preventing the characteristic loss in animal production during the dry winter months of the year (Bisschop & du Toit, 1929; Murray, Romyn, Haylett & Ericksen, 1936; Murray & Romyn, 1937; Kotze, 1948; Rhodes, 1956; Skinner, 1963; Bisschop, 1964; Shur, 1968; Ward, 1968; van Schalkwyk & Lombard, 1969).

In spite of the vast volume of work that has been conducted, the interaction between protein, energy and phosphorus in preventing winter loss has not been critically evaluated and this aspect of supplementary feeding remains poorly understood. The purpose of this experiment was therefore to test the effect of protein, energy and phosphorus, supplemented either alone or in all possible combinations, on food intake and bodymass change in animals fed low-quality roughage under controlled feeding conditions.

Procedure

Animals

A total of 96 British-crossbred oxen between 6 and 10 months of age were used. Young growing cattle were deliberately chosen since they would have the potential to respond to the treatments applied. On arrival at the experimental unit, a period of 14 days was allowed for the animals to adapt to the

facilities. During this period they were given free access to dry baled sugarcane tops, were treated with 375 000 I.U. vitamin A (Rouche ADE injectable) and immunized against various diseases. In order to increase the precision of the bodymass measurement, both the initial and final bodymass was determined by taking the average non-starved bodymass as determined on three consecutive days in each case. Intermediary masses were recorded at 2-weekly intervals.

Treatments

The 96 experimental cattle were stratified according to initial bodymass and divided into eight groups under conditions of restrictive randomization. A $2 \times 2 \times 2$ factorial arrangement of treatments was used. The factors investigated were crude protein (185 g/day versus 0 g), energy (2,8 MJ/day versus 0 MJ), and phosphorus (6,0 g/day versus 0 g). At the higher levels in each comparison, the animals would receive about 60%, 10% and 50%, respectively, of their daily protein, energy and phosphorus needs in supplementary form which excluded the nutrients they would derive from the roughage. The lower levels of no energy, no protein and no phosphorus, represent the theoretical target, which was of course not 100% possible, because of the unavoidable small contributions of the carrier feed.

The crude protein supplement was made up of a combination of true protein in the form of prime gluten, and urea, with NPN making up about 75% of the protein equivalent. Molasses served as the main source of energy whereas monocalcium phosphate served as the main source of phosphorus (see Table 1).

To ensure that salt and trace minerals would not limit animal response to the feed supplements, the cattle in all groups were given 25 g salt per day, a trace mineral supplement compounded to supply about 50% of their daily NRC trace mineral requirements and free access to coarsely milled roughage, consisting of sugarcane tops. One end of the feed trough of each group was used to feed the daily ration of supplementary feed while the rest of the feed trough was used to give the animals free access to sugarcane tops.

The levels of supplementation used in this experiment were

chosen to be similar to the levels commonly used in winter lick supplements. Although the level of energy supplementation is low in relation to the animals' daily requirements, this is nevertheless typical of the level used under practical conditions.

The sugarcane tops contained, on a dry matter basis, 36,2 g/kg crude protein, 2,78 g/kg Ca, 0,81 g/kg P and 375 g/kg crude fibre, 52 g/kg ash, and an estimated metabolizable energy value of 8,39 MJ/kg. Tops contained 86,4% dry matter. Sugarcane tops were used because of their ready availability and because of their similarity in composition to dry veld grazing during the winter months.

Results

Roughage intake

The actual ingredients and nutrient intakes of the supplements are shown in Table 1. The lower levels of nutrients in the control groups, represent the unavoidable contributions of the carrier feeds to the factors being investigated. The influence of the various supplements on roughage intake and mass loss is summarized in Table 2. Low-level energy supplementation had a very small influence on voluntary roughage intake. When given as the sole supplement, energy supplementation depressed roughage intake by 2,9% (Treatment 6 versus 8).

In all other combinations energy supplementation resulted in a slight improvement in roughage intake with the best response ($\pm 3,9\%$) being obtained where energy was supplemented with protein but in the absence of phosphorus treatment (Treatment 2 versus 4).

Phosphorus supplementation, in most instances, had a negative effect on roughage intake. This effect was most marked where phosphorus was given on its own and where it depressed voluntary feed intake by as much as 5,9% (Treatment 7 versus 8). In combination with protein as the only other supplement (Treatment 3 versus 4), phosphorus did not stimulate or depress roughage intake.

In contrast with energy and phosphorus, protein supplementation in all combinations had a dramatic effect on improving roughage intake. This result is, of course, in common with that of practically all other research findings

Table 1 Actual daily intake of lick constituents and actual intake of nutrients calculated over a 70-day experimental period

Item	Protein				Control			
	Energy		Control		Energy		Control	
	P	Control	P	Control	P	Control	P	Control
Treatment No.	1	2	3	4	5	6	7	8
Ingredient intake (g/day):								
Ammonium sulphate	9,8	10,3	8,7	7,6	—	—	—	—
Maize prime gluten	69	73	62	54	—	—	—	—
Urea	40	42	39	34	—	—	—	—
Molasses	146	154	94	6	211	213	—	—
Monocalcium phosphate	25	—	22	—	28	—	28	—
Salt	25	26	21	19	25	25	25	29
Milled bagasse pith pellets	48	51	—	—	106	107	—	—
Limestone	1,1	—	3,2	0,9	—	—	2,0	—
Trace mineral premix	0,28	0,27	0,24	0,21	0,28	0,28	0,28	0,32
Supplementary nutrient intake:								
Crude protein (g/day)	179	188	165	144	12	12	0	0
ME (MJ/day)	2,87	2,96	1,29	0,82	3,08	2,89	0	0
Ca (g/day)	6,0	0,9	5,7	0,7	6,4	1,3	5,9	0
P (g/day)	5,9	0,6	5,2	0,4	6,0	0,2	5,9	0

Table 2 Feed intake and livemass change in oxen fed supplementary licks over a 70-day experimental period

Item	Protein				Control			
	Energy		Control		Energy		Control	
	P	Control	P	Control	P	Control	P	Control
Treatment No.	1	2	3	4	5	6	7	8
Number of cattle	12	12	12	12	12	12	12	12
Initial livemass (kg)	181,2	181,2	181,7	183,0	181,2	181,2	186,1	184,2
Final livemass (kg)	177,8	177,4	174,9	178,1	159,1	163,8	165,6	165,7
Livemass gain (kg)	-3,4	-3,8	-6,8	-4,9	-22,1	-17,4	-20,5	-18,5
ADG (kg)	-0,049	-0,054	-0,097	-0,070	-0,316	-0,249	-0,293	-0,264
Daily lick intake ^a (kg)	0,364	0,356	0,250	0,191	0,371	0,345	0,055	0,029
Daily cane-top intake ^b (kg)	3,217	3,299	3,180	3,175	2,359	2,423	2,301	2,496
Total intake (kg)	3,581	3,655	3,430	3,366	2,730	2,768	2,356	2,525
Total protein intake (g/d)	280	291	265	243	86	88	72	78
Total ME intake (MJ/d)	26,19	26,88	24,35	23,84	20,18	20,46	16,68	18,10
Total Ca intake (g/d)	13,7	8,8	13,3	8,3	12,1	7,1	11,4	6,0
Total P intake (g/d)	8,2	2,9	7,4	2,6	7,7	1,9	7,5	1,7

^aAir-dry basis^bAir-dry basis, 86,4% dry matter

in this field. It is of interest, however, to note that the improvement in roughage intake was at its lowest (27,7%) where protein was given as the sole supplement (Treatment 4 versus 8) whilst in all other combinations with energy and phosphorus the improvement varied between 36,2% and 38,2%.

Mass gains

Low-level energy supplementation had a relatively minor influence on livemass change as would be expected from its limited effect on roughage intake. Energy supplementation was most beneficial in the presence of protein and phosphorus (3,4 kg less mass lost) but it induced a greater mass loss of 1,6% if supplemented in combination with phosphorus but without protein.

Phosphorus supplementation, in three out of four comparisons, induced an increased rate of livemass loss. Only in the presence of both protein and energy (Treatment 1 versus 2) was there a small positive response (0,4 kg less mass lost) resulting from phosphorus supplementation.

In the two protein-supplemented groups the combined negative effect of phosphorus supplementation (0,75 kg increased lost) was less marked than in the two groups where protein was not supplemented (3,4 kg increased mass lost).

Protein supplementation, as would be expected from its positive effect on feed intake, had a highly significant effect ($P < 0,01$) on reducing the rate of livemass loss. The groups not receiving protein supplementation lost an average of 19,6 kg over the 70-day experimental period whereas the protein-supplemented groups lost an average of only 4,7 kg livemass. The overall (main effect) improvement was therefore 14,9 kg owing to protein supplementation. There was a tendency for protein supplementation to give slightly better results in the presence of both energy and phosphorus supplementation. Phosphorus supplemented in isolation with protein, had no beneficial effect on bodymass.

Discussion

The results of this experiment confirm the basic concepts that have been established to date regarding the effects of protein, energy and phosphorus on feed intake and bodymass of animals consuming low-quality, protein-deficient forages. The

finding that energy supplementation has a relatively minor influence on roughage intake and in preventing mass loss is in agreement with results published by Rhodes (1956); Verbeek & Von la Chevallerie (1959); Nel & van Niekerk (1970); Winks, Alexander & Lynch (1970); and Winks & Laing (1972). Both Verbeek, & Von la Chevallerie (1959) and Winks & Laing (1972) found that molasses as the sole energy source accentuated mass loss in animals being supplemented on dry native grasslands. The negative effect which energy supplements have when given as the only supplement on protein-deficient forage is borne out by the results reported in this article. The lack of response or even negative reaction to energy supplements under these conditions can be attributed to the fact that such supplements cause a proliferation of fast-growing sugar or starch digesting micro-organisms which deprive the slower growing cellulolytic organisms of what little nitrogen is available in the rumen (Gilchrist & Schwartz, 1972). The net effect is a lowering of digestibility, rate of passage, and voluntary intake of roughage.

Many experiments, conducted both in southern Africa and elsewhere (Bisschop & du Toit, 1929; Murray & Romyn, 1937; Kotze, 1948; Rhodes, 1956; Bisschop, 1964; Shur, 1968; Ward, 1968; van Schalkwyk & Lombard, 1969), have shown that grazing animals only respond, in terms of livemass, to phosphorus supplementation during that period of the year in which they are gaining bodymass. There are in fact several reports which show that where phosphorus is given as the only dry season supplement, it may accelerate the rate of livemass loss (Shur, 1968; Ward, 1968; Anonymous, 1970; Winks & Laing, 1972) and this finding is also confirmed by the current experiment. Our results show that although sugarcane tops contained phosphorus at a level of only 0,81 mg/kg DM, phosphorus is not the primary limiting nutrient under these conditions. We believe that the negative effect of phosphorus supplementation on roughage intake and livemass under these circumstances is attributable to the fact that phosphorus supplementation is causing a further imbalance in an already imbalanced diet. The animal, which is already in a negative phosphorus balance because of bodymass loss, is being burdened with an additional intake of phosphorus which it does not require.

Protein supplementation, in contrast to both energy and

phosphorus, had a marked stimulating effect on forage intake. Protein, either on its own or in all combinations with either energy or phosphorus, greatly reduced the rate of livemass loss. The fact that protein supplementation improved intake of low-quality roughage and reduced rate of livemass loss under these conditions is of course in agreement with the numerous studies in which the effects of protein supplementation on digestibility, roughage intake and animal performance have been studied. These experiments, with special reference to southern Africa have been thoroughly reviewed by Pieterse (1966), Topps (1971), and van Niekerk (1974).

The main object of this particular study was, however, to establish the nature of any interactions between protein, energy and phosphorus supplements. From these results it is evident that there was a tendency for protein supplementation to give better results in the presence of energy, although this interaction was not statistically significant ($P > 0,05$). The response to protein supplementation was only improved by phosphorus supplementation when protein, energy and phosphorus were given simultaneously. It can be assumed that the response to both energy and phosphorus supplementation would be greater under conditions which would allow animals to gain in mass rather than to be in a state of negative mass balance as experienced in this experiment. This could be particularly relevant where growing animals or reproductive females are fed at higher levels of nutrition which are sufficiently high to allow for a positive mass, and therefore, nutrient balance. That the vast majority of animals wintered on grassveld in southern Africa are in a state of negative mass balance, in spite of supplements, is a reality that must be accepted.

It may therefore be concluded that protein supplements will markedly and significantly ($P < 0,01$) reduce the rate of mass loss in animals being maintained on low-quality forage. Phosphorus and low-level energy supplements given on their own, were found to have no effect in reducing the rate of mass loss under these circumstances. The value of protein supplementation was slightly enhanced by combining the protein supplement with energy and phosphorus but this improvement was not statistically significant ($P > 0,05$). This experiment, conducted under conditions which closely simulate conditions which exist on winter grassveld, confirms the general belief that protein is the major or first limiting nutrient under these farming conditions.

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