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UREA IN SUPPLEMENTS FOR GROWING YOUNG CATTLE ON VELD GRAZING IN THE DRY SEASON

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OPSOMMING: UREUM IN BYVOEDING VIR GROEIENDE JONG VLEISBEESTE OP VELDWEIDING GEDURENDE WINTER

Die invloed van toenemende vervanging van katoensaad-oliekoekmeel met ureum in byvoeding, met 'n ekwivalente stikstof inhoud (40 persent RP), van groeiende speen-osse is ondersoek oor 'n tydperk van drie jaar. Ses groepe van 30 Hereford x Afrikaner speenosse was soos volg op veldweiding gevoer; 500 g daagliks van 'n voerpil bevattende 0, 2, 4, 6 of 8 persent ureum en 'n kontrole groep sonder byvoeding. Die massa prestasie van die osse het verminder met die vermeerdering in peil van ureum in die byvoeding. Hierdie afname gemeet in terme van karkas massa verandering, was hoogs betekenisvol ($P < 0{,}001$) en kan beskryf word deur die volgende vergelykings: $Y = 16{,}38 - 0{,}76X$ ($r^2 = 0{,}92$) of $Y = 15{,}81 - 0{,}19X - 0{,}07 X^2$ ($r^2 = 0{,}96$) waar Y die voorspelde karkasmassa respons en X die ureumpeil in die byvoeding is Gebasseer op bogenoemde vergelykings word 'n skatting gegee van doeltreffendheid van benutting van ureum in die byvoeding en die optimale inhoudspeil word aldus gedefinieer.

SUMMARY:

The effect of replacing increasing amounts of cottonseed cake meal with urea in isonitrogenous (40 per cent CP) supplements for growing weaner steers has been investigated over a period of three years. Each year six groups of 30 Hereford x Afrikander weaner steers were fed, either no supplement (control) or 500 g per head daily of a cube containing 0, 2, 4, 6 or 8 per cent urea during winter, while grazing veld. The performance of the steers declined as the level of urea in the supplements increased. This decline, measured in terms of carcass mass change, was highly significant ($P > 0{,}001$) and could be described by the equations: $Y = 16{,}38 - 0{,}76X$ ($r^2 = 0{,}92$) or $Y = 15{,}81 - 0{,}19X - 0{,}07 X^2$ ($r^2 = 0{,}96$) where Y is the predicted carcass mass response and X the level of urea in the supplement. An estimate is given, based on the above equations, for the efficiency of utilization of urea in the supplements and, consequently, the optimal level of inclusion is defined.

Rhodesia experiences markedly seasonal rainfall with effective rain between November and April. The crude protein content of the veld corresponds with the growth pattern of the grass and may be 9 to 10 per cent on a day matter (DM) basis in the early growing season and declines to 2 per cent in the late dry season (Elliott & Folkersten, 1961). While the ruminant's ability to graze selectively moderates the effects of these drastic changes in herbage quality, the level of crude protein in veld in the dry season is too low to support maintenance of body mass. It is for these reasons that it is common practice to feed protein-rich supplements.

It has long been recognised that urea, and other non-protein nitrogenous compounds, can replace a proportion of dietary protein for ruminants. There is now a clearer understanding than hitherto of the mechanism by which this is possible but there remain areas of speculation. It is known that when urea is fed to ruminants it is rapidly hydrolysed to ammonia and carbon dioxide by the action of microbial urease in the reticulorumen. The ammonia-N thus released in combined with alpha-keto acids to synthesize amino acids, which are then converted to microbial protein and subsequently digested by enzyme action further down the digestive tract (Tillman, 1967). There are many factors which influence the efficiency of use of urea-N by ruminants and these have been comprehensively reviewed, e.g. Reid (1953), Tillman (1967), Chalupa (1968), Kempton, Nolan and Leng (1977).

Provision of additional N to animals on a diet of poor quality roughage increases microbial activity, increases rate of fermentation and rate of passage of ingesta through the digestive tract and thereby enhances voluntary intake of herbage and the energy status of the grazing animal. Because of low unit N cost, urea is widely used in commercial protein supplements for ruminants but frequently at levels probably too high for efficient utilization. To define optimal limits in the use of urea by the grazing animal, a series of trials was conducted over the dry seasons of 1974 to 1976, in which urea progressively replaced natural protein in supplements fed to weaner steers on veld grazing.

Experimental Procedure

Hereford x Afrikaner weaner steers of approximately 190 to 225 kg body mass were purchased each year for a period of three years for the experiments. They were weighed, ranked according to body mass, ear-tagged and allocated by mass to seven groups of 30 steers each.

One group was slaughtered each year at the start of the experiment and the relation between body mass and hot dressed carcass mass of these animals was determined. These equations, which were used to estimate the initial carcass mass of the six groups of experimental animals, were as follows:-

1974 $Y = 0{,}64\mathbf{X} - 26{,}21$ ($\mathbf{r}^2 = 0{,}75$) ($\mathbf{n} = 30$)
1975 $\mathbf{Y} = 0{,}50\mathbf{X} - 1{,}47$ ($\mathbf{r}^2 = 0{,}78$) ($\mathbf{n} = 30$)
1976 $\mathbf{Y} = 0{,}56\mathbf{X} - 11{,}20$ ($\mathbf{r}^2 = 0{,}79$) ($\mathbf{n} = 30$)

where **Y** is hot dressed carcass mass and **X** is body mass.

The experimental groups were offered 15 kg daily (500 g per head) of a pelleted supplement made up as follows:-

Table 1

Constituents of supplements containing 40 per cent CP equivalent

Group	Cotton-seed cake meal	Maize meal	Monocal-cium phos-phate	Urea
1	No additional food (control)			
2	100,0	–	–	–
3	82,5	14,6	0,9	2,0
4	66,0	28,2	1,8	4,0
5	50,0	41,3	2,7	6,0
6	34,5	53,9	3,6	8,0

The supplements were formulated to contain approximately the same level of crude protein (40 per cent). Feeding of supplements started in early June each year and finished at the end of October.

The six groups of experimental steers each year grazed six 25 ha veld paddocks which comprised some *Brachystegia spiciformis* woodland with predominantly *Hyparrhenia spp* and approximately one-third of the area was vlei land with typical vlei grasses, as described by Rattray (1957). The groups were alternated between the camps at weekly intervals to equalise the quality of grazing on offer to the animals.

All steers were weighed and dipped at fortnightly intervals throughout the experimental period.

At the end of each dry season a group of steers, representative of the body mass of each treatment group, (10 steers each, 60 steers in all) was slaughtered and the relation between hot dressed mass and body mass of these animals was used to estimate the final carcass mass of all steers in each group. The performance of the steers over the dry season was thus assessed in terms of both body mass change and estimates of carcass mass change.

Data from all three years, comprising 540 animals in all, were pooled for the statistical analyses.

Results

Body and carcass mass changes of the steers over the three dry seasons are summarized in Table 2.

All groups of steers, whether fed or not, lost carcass mass, although some groups showed slight body mass gains.

The response to the supplements, i.e. the difference in body and carcass mass between supplemented groups, is given in Table 3.

Results in the three years were remarkably consistent. All supplements reduced body and carcass mass losses, and in some case, caused slight body mass gains. There was little difference in performance (carcass mass changes) between steers fed urea free cubes (cottonseed cake meal) and those fed cubes containing 2 per cent urea. However, there was a marked decline in performance of steers as the level or urea in the supplements increased. This decline was highly significant ($P > 0{,}001$) and could be described by either a linear or curvilinear relationship: $\mathbf{Y} = 16{,}38 - 0{,}76\ \mathbf{X}$ ($r^2 = 0{,}104$) $\mathbf{Sy.x} = 6{,}356$ ($\mathbf{n} = 450$) or $\mathbf{Y} = 15{,}81 - 0{,}19\ \mathbf{X} - 0{,}07\ \mathbf{X}^2$ ($r^2 = 0{,}109$) $\mathbf{Sy.x} = 6{,}345$ ($\mathbf{n} = 450$) where **Y** is the predicted carcass mass response and **X** the level of urea in the supplement. (In each case analysis was based on five levels of urea x 30 animals x three years, adjusted for controls.) The quadratic equation was considered a more appropriate fit, though this could not be proved statistically.

The rate of decline in performance with increasing levels of urea tends to be over-estimated by measuring change in body mass (Table 3). Body mass change is therefore an unreliable parameter for assessing animal

Table 2

Body and carcass mass (kg) of the steers over the dry season (mean of three years 1975 – 1976)

	No supplement	Cottonseed cake meal	2% urea	4% urea	6% urea	8% urea
Initial body mass	205,4	205,6	205,7	205,4	205,5	205,2
Final body mass	181,9	210,4	207,5	201,8	201,8	194,6
Body mass gain/loss	– 23,5	+ 4,8	+ 1,8	– 3,6	– 3,7	– 10,6
Initial carcass mass	103,4	103,5	103,5	103,5	103,4	103,4
Final carcass mass	81,4	97,3	97,2	94,6	93,9	90,9
Carcass mass loss	– 22,0	– 6,2	– 6,3	– 8,9	– 9,5	– 12,5

Table 3

Mean initial body and carcass mass and responses (kg) of steers to supplements containing different proportions of urea*

		Mean initial mass	Cotton-seed cake meal	2% urea	4% urea	6% urea	8% urea
1974	Body	189,7	28,5	31,5	29,6	20,4	18,6
	carcass	95,4	13,7	16,4	13,5	10,9	9,9
1975	Body	203,5	30,8	16,9	15,9	20,2	14,0
	carcass	100,3	15,5	15,1	11,8	12,5	10,1
1976	Body	223,2	25,0	29,3	13,4	18,2	5,5
	carcass	114,7	17,9	15,3	14,4	14,2	8,5
Mean	Body	205,5	28,1	25,9	19,6	19,6	12,7
	carcass	103,5	15,7	15,6	13,2	12,5	9,6

* Changes in carcass and body mass compared with unfed controls

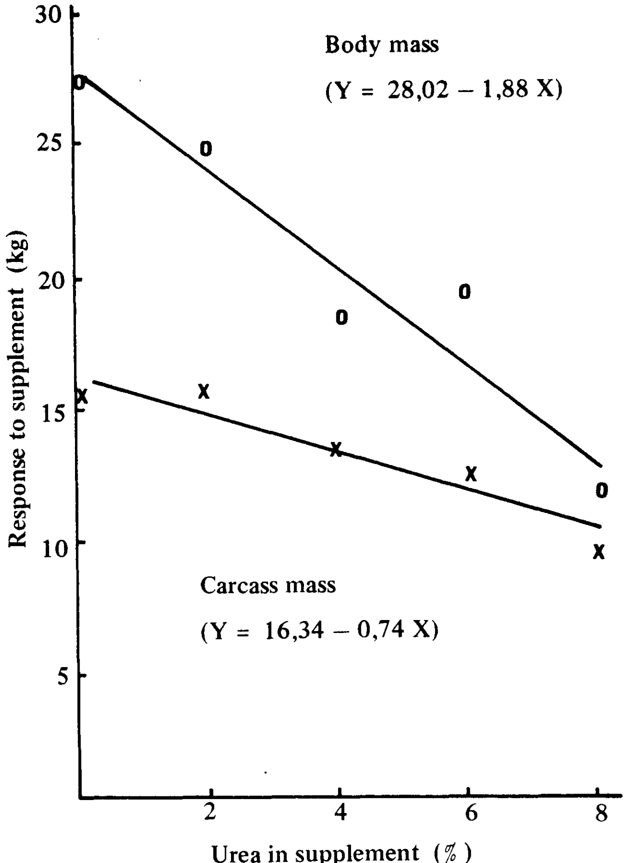

Fig. 1. Response to urea containing supplements in terms of bodymass and carcass mass change in growing steers

performance, particularly where diets or supplements being evaluated differ in quality. This is illustrated in Fig. 1.

Body mass change $Y_1 = 28{,}60 - 1{,}86X$ ($r^2 = 0{,}94$)
Carcass mass change $Y_2 = 16{,}38 - 0{,}76X$ ($r^2 = 0{,}92$)

where X is the level of urea in the supplement. (For the purpose of this comparison the linear estimate is used). The expensive technique of assessing animal performance in terms of estimates of carcass mass change, due to the large number of unfinished animals required to be slaughtered, is justified under these circumstances.

From the data presented above an estimate can be made of the efficiency with which urea was used in these supplements, based on the assumptiom that the natural protein in the supplement is used with the same efficiency, whether fed in the presence of or the absence of urea. While this assumption may not be valid, since there is no way of biologically separating the relative contribution of N from protein and urea to microbial synthesis, nevertheless by including urea in protein supplements for ruminants, it is presumed that the contribution of urea-N is additive. This estimate is given in Table 4 using the linear model and in Table 5 using the quadratic model shown above.

If the decline in performance (carcass mass change) with increasing levels of urea is linear, then the utilization of urea is constant at all levels up to 8 per cent in the diet and of the order of 35 per cent. However, this is unlikely since, in practice, there was little reduction in performance by including 2 per cent urea in the supplement, while at 8 per cent urea, the performance was lower than that predicted by the linear equation (Table 3). If the decline in performance is best described by the quadratic equation, and this seems more likely, then the utilization of urea declined from 70 per cent at the low (2 per cent) level to little over 30 per cent at the high (8 per cent) level. In fact the level of response predicted by the quadratic equation at the two extremes agrees closely with that observed in practice. This trend was very similar to that observed by Clanton (1978).

Discussion

It is generally accepted, and this was confirmed in the present study, that urea is used less efficiently than natural proteins in the diets of ruminants. This is probably because some of the natural protein escapes ruminal proteolysis and passes directly to the abomasum (Chalupa, 1968) and the magnitude of this fraction depends on the solubility of the protein source and the rate of flow of ingesta from the rumen. This superiority of "by-pass" proteins is due in part to the supply of essential amino acids to the abomasum, since microbial protein may lack these (especially the S-containing amino acids, methionine and cystine (McDonald, 1968)) and is also due in part to the supply of "glucogenic" amino acids which assist in meeting glucose requirements (Kempton *et al.*, 1977; Topps, 1975). Quality of dietary protein in ruminant rations is therefore important, despite the capacity of ruminal micro-organisms for protein synthesis.

Furthermore, the rate of urea hydrolysis in the rumen is very rapid with consequently a very rapid release of ammonia. Bloomfield, Garner and Muhrer (1960) have shown that urea hydrolysis occurs four times faster than the uptake of ammonia, which results in a considerable loss of ammonia-N that would otherwise by available for protein synthesis. Ammonia is rapidly absorbed into the blood and, though some is converted to urea in the liver and re-cycled via the saliva or by direct diffusion in the rumen via the blood, some is excreted in urine and lost. In addition, ruminal pH is high in animals grazing dry herbage in winter (Topps, Reed & Elliott, 1965) and the rate of ammonia absorption increases as pH rises. Ammonia more rapidly penetrates the lipid layers of the rumen mucosa than the ammonium ion (Bloomfield, Kearly, Creach & Muhrer, 1963) and under acid conditions the ammonia-N is more readily converted to the ammonium ion so that absorption is relatively slow. During urea feeding, however, pH is ele-

Table 4

An estimate of the efficiency with which urea was utilized (Linear model)

a	b	c	d	e	f	g
% urea	Est. gain	Protein %	Expected prot. gain	Actual urea gain	Expected urea gain	Utilization %
0	16,38	100,0	16,38	–	–	–
2	14,86	85,6	14,02	0,84	2,36	35,6
4	13,33	71,3	11,68	1,65	4,70	35,1
6	11,80	57,0	9,34	2,46	7,04	34,9
8	10,27	42,6	6,98	3,29	9,40	35,0

Table 5

An estimate of the efficiency with which urea was utilized (Quadratic model)

a	b	c	d	e	f	g
% urea	Est. gain	Protein %	Expected prot. gain	Actual urea gain	Expected urea gain	Utilization %
0	15,81	100,0	15,81	–	–	–
2	15,14	85,6	13,53	1,61	2,28	70,6
4	13,90	71,3	11,27	2,63	4,54	57,9
6	12,08	57,0	9,01	3,07	6,80	45,1
8	9,70	42,6	6,74	2,96	9,07	32,6

Where (both tables):

(a) is the level of urea in the supplement;

(b) is the estimated or "smoothed" response curve (carcass mass) from the linear or quadratic models shown above;

(c) is the proportion of crude protein in the supplement contributed by cottonseed cake meal (and the small amount of maize meal);

(d) is the expected contribution to the total gain by cottonseed cake meal;

(e) is the estimated contribution to the gains made by urea (b – d);

(f) is the expected contribution made by urea (16,38 – d, Table 4) (15,81 – d, Table 5);

(g) is the urea utilization per cent $\left(\frac{e}{f} \times 100\right)$.

vated, and the buffering capacity of rumen fluid against alkaline conditions is less well established than against the acid conditions occurring during volatile fatty acid production (Bloomfield, Komer, Wilson & Muhrer, 1966). Thus conditions in the rumen during the feeding of urea favour not only rapid production, but also rapid absorption of ammonia.

While urea is a satisfactory substitute for natural protein supplements in ruminant rations which contain a high level of grain (Tillman, 1967), as corn starch is a particularly suitable substrate for urea utilization (Bloomfield, Muhrer & Pfander, 1958), less is known of the efficiency of urea utilization in supplements for cattle on range conditions. The principle of supplementary feeding of limited rations to grazing cattle does not lend itself to efficient use of urea. Generally, the supplement is consumed rapidly and the roughage as the main source of energy is hydrolysed too slowly to be effective in the uptake of ammonia. The level at which urea can be economically included in protein-rich supplements therefore requires examination.

Before attempting to define this level there are certain factors to consider:

Firstly, the factors involved in the efficient utilization of urea are numerous and include: the nature of the diet particularly the source and level of the carbohydrate and protein components; the mineral content; the frequency of feeding and consequently their effect on rumen pH.

Secondly, the response to non-protein N depends on the protein requirements (physiological state) of the animal. When the requirement is equal to or less than that of microbial protein supply, non-protein-N may supply practically all of the animal's needs. However, when the requirements exceed microbial production, e.g. during early growth, late pregnancy or peak lactation, non-protein-N cannot supply all the animal's needs and additional dietary protein must be fed (Ørskov, 1970). Furthermore, if microbial-N requirements are met from the basal diet, response to the addition of urea is likely to be minimal (Ørskov, Fraser & Corse, 1970).

Thirdly, because of the close interrelationship between protein and energy in the diet of ruminants, it is impossible to predict the response to urea in a ration without knowing the energy intake of the animal. When intake is optimal, response to urea may be similar to that of natural protein, whereas on a limited energy intake, such as when animals graze poor quality veld in winter, responses to urea and natural protein differ (Balch, 1967). Under these circumstances urea could be utilized inefficiently. Additional protein to such a diet could be partly used as a source of energy while the hydrolysis of urea yields no energy.

Clearly, establishing the optimum level of urea in supplements for grazing ruminants is complicated. There are decided advantages in using urea as a source of N in ruminant rations (availability, concentration, solubility and mainly cost per unit N) but levels should not be so high that depressed performance offsets savings in cost. There are traditionally accepted guide-lines that urea should not exceed one-third of the total N in the diet (Reid, 1953; Maynard & Loosli, 1956; Barnett & Reid, 1951; Tillman, 1967; Chalupa, 1968; Carr, 1973) and results from the present study appear to agree with this level. From Table 5, at the 4 per cent level (approximately 30 per cent of the total N in the supplement or 20 per cent of the total N in the diet, including the small intake of protein from herbage) urea effectively replaced four parts of cottonseed cake meal and this is the approximate ratio of the price of oil cake meals to urea (on an equivalent N basis) in this country. Therefore there appears to be no advantage in including urea at higher levels in supplements of this nature to growing steers. Any additional saving in cost by using more urea is offset by reduced performance.

It is because of this price ratio that urea is frequently used as a 'cheap' source of N to supplement the diet of livestock on poor quality roughage and there is no doubt that urea has an important role to play in this regard, particularly as oilcake meals become more costly. However, as a partial replacement for high quality natural proteins in supplements to weaners, it is less successful and its success diminishes rapidly as levels increase.

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References

BALCH, C.C., 1967. Problems in predicting the value of non-protein nitrogen as a substitute for protein in rations for farm animal ruminants. *World Rev. Anim. Prod.* 3, 84.

BARNETT, A.J.G. & REID, R.L., 1961. *Reactions in the rumen.* London: Edward Arnold Ltd.

BLOOMFIELD, R.A., MUHRER, M.E. & PFANDER, W.H., 1958. Relation of composition of energy source to urea utilization by rumen micro-organisms. *J. Anim. Sci.* 17, 1189.

BLOOMFIELD, R.A., GARNER, G.B. & MUHRER, M.E., 1960. Kinetics of urea metabolism in Sheep. *J. Anim. Sci.* 19, 1248.

BLOOMFIELD, R.A., KEARLY, E.O., CREACH, D.O. & MUHRER, M.E., 1963. Ruminal pH and absorption of ammonia and VFA. *J. Anim. Sci.* 22, 883.

BLOOMFIELD, R.A., KOMER, E.G., WILSON, R.P. & MUHRER, M.E., 1966. Alkaline buffering capacity of rumen fluid. *J. Anim. Sci.* 25, 1276.

CARR, P.M., 1973. *Urea for grazing sheep and cattle.* Ext. Bull. No. 12. Dept. of Agric., South Australia.

CHALUPA, W., 1968. Problems in feeding urea to ruminants. *J. Anim. Sci.* 27, 207.

CLANTON, D.C., 1978. Non-protein nitrogen in range supplements. *J. Anim. Sci.* 47, 765.

ELLIOTT, R.C. & FOLKERSTEN, K., 1961. Seasonal changes in composition and yields of veld grass. *Rhod. Agric. J.* 58, 186.

KEMPTON, T.J., NOLAN, J.V. & LENG, R.A., 1977. Principles for the use of non-protein nitrogen and by-pass proteins in diets of ruminants. *World Animal Review* Vol. 22.

MAYNARD, L.A. & LOOSLI, J.K., 1956. *Animal Nutrition.* New York: McGraw-Hill Book Co.

McDONALD, I.W., 1968. Nutritional aspects of protein metabolism in ruminants. *Aust. Vet. J.* 441, 145.

ØRSKOV, E.R., 1970. Nitrogen utilization by the young ruminant. In: *Proceedings of the 4th Nutrition Conference for Feed Manufacturers.* University of Nottingham, U.K. Eds. H. Swan & D. Lewis.

ØRSKOV, E.R., FRASER, C. & CORSE, E.L., 1970. The effect on protein utilization of feeding different protein supplements via the rumen or via the abomasum in young growing sheep. *Br. J. Nutr.* 24, 803.

RATTRAY, J.M., 1957. The grasses and grass associations of Southern Rhodesia. *Rhod. Agric. J.* 54, 197.

REID, J.T., 1953. Urea as a protein replacement for ruminants. A review. *J. Dairy Sci.* 36, 955.

TOPPS, J.H., REED, W.D.C. & ELLIOTT, R.C., 1965. The effect of season and of supplementary feeding on the rumen contents of African cattle grazing sub-tropical herbage. 2. pH values, concentration and proportions of volatile fatty acids. *J. Agric. Sci. (Camb).* 64, 397.

TOPPS, J.H., 1975. *Protected proteins – their potential importance and future uses.* The Rhodesian Branch of the South African Society for Animal Production. Misc. Pub.

TILLMAN, A.D., 1967. *Urea utilization by ruminant animals.* Oklahoma State University Experiment Station. Misc. Pub. M.P. 79.