

COPRA MEAL AS A SUPPLEMENT TO CATTLE OFFERED A LOW QUALITY NATIVE PASTURE HAY

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Summary

Twenty-four Hereford steers, 22 months old and a mean liveweight (\pm s.e.) of 250 ± 7 kg were used in an experiment to evaluate over 42 days two rates of copra meal supplementation to cattle on a low N (8.6 ± 0.9 g N/kg dry matter (DM)), low digestible ($45 \pm 5.2\%$ DM) native pasture hay. Steers given the two rates (500, 1000 g/steer/day; i.e. 500C, 1000C) were compared to steers on a non-supplemental diet and to the effects on steers of supplemental urea (30 g/steer/day; 30U) or with copra meal (500 g/steer/day; 500C.U), or of cottonseed meal (500 g/steer/day; 500S). Liveweight change was increased ($P < 0.01$) by all of the supplements except by supplemental urea. The most effective treatment, 1000C, increased significantly ($P < 0.01$) liveweight change (946 g/day) in steers above all supplements except those steers given 500C.U (718 g/day). Hay intake per unit liveweight was increased ($P < 0.05$) by 7% by the 30U and 500C.U treatments, and by 9% by 500C; this group having the highest intake. The feed conversion efficiency by the steers was improved significantly ($P < 0.05$) by all the supplements, being greatest ($P < 0.05$) for the 1000C group (6.0 g feed intake/g gain) and least for the 500S supplemented group (11.5 g/g gain). Efficiency was lowest (18.6 g/g gain) for the non-supplemented steers on the basal hay diet. Copra meal N was less degradable (i.e. 29%) in nylon bags over 15 hours in the rumen than was cottonseed meal N (37%), and rumen ammonia concentrations were lower ($P < 0.05$) in cattle supplemented with copra meal (25, 27 mg N/L) than in cattle given urea (36 mg N/L) or cottonseed meal (39 mg N/L). It is concluded that copra meal at a daily rate of 500 g/head, and with rumen soluble nitrogen from urea, is an effective supplement for improving growth of cattle on a low quality forage.

(Key Words: Protein Meals, Copra Meal, Cottonseed Meal, Cattle, Low Quality Hay)

Introduction

Extensive weight losses and mortalities in cattle herds are a problem during the dry seasons of tropical and subtropical Australia because of the low quality of the native pastures which form the predominant forage of the grazing herds. Supplements, especially nitrogen-sulphur and energy rich ones have been recommended for overcoming the nutritional deficiencies that are at the basis of such weight losses (Winks, 1984). Cottonseed meal is one of the most effective supplements used in these areas (Lindsay *et al.*, 1982; Hennessy

et al., 1981; Hennessy and Williamson, 1988a) being used far more efficiently than urea and sulphur (Hunter and Siebert, 1980). The responses to these supplements have been attributed in a large part to the proteins that are undegraded in the rumen and pass onto the intestine for digestion, also providing additional nitrogen for microbial cell synthesis in the rumen. However, most of the cottonseed meal is produced outside the tropical areas wherein lies its greatest potential use. Consequently, transport of the meal to tropical areas adds to the cost of supplementation and reduces the marginal return from this practice in tropical Australia. Copra meal, from Papua New Guinea and South Pacific Islands, is available in Northern Queensland at prices generally far less than cottonseed meal. Copra meal is processed differently from cottonseed meal, and contains approximately half the protein content but considerably more oil. As yet there is no critical information

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Received November 16, 1988

Accepted March 16, 1989

on the usefulness of copra meal as a supplement to cattle. In this study, the feed intake, liveweight change and feed conversion efficiency of steers on a low nitrogen (N), low digestible forage are compared when the steers have been supplemented with urea, cottonseed meal, copra meal or copra meal with urea.

Materials and Methods

Animals and forage

Twenty-four Hereford steers, 22 months old and a mean liveweight (\pm s.e.) 250 ± 7 kg were allocated to six treatment groups by stratified randomisation according to liveweight. The steers were injected with Avomec (10 g/l Avermectin B₁; Merck, Sharp and Dohme, Aust.) for the control of internal and external parasites, and placed in single pens under cover. The steers were fed a low quality grass hay for 10 days, and then for a further 42 days during which time supplements were offered according to the treatment group.

The treatment groups were: No supplement (Basal), copra meal at 500 g/steer/day (500C) and 1000 g/steer/day (1000C), urea at 30 g/steer/day (30U) and with 500 g/steer/day of copra meal (500C.U), and cottonseed meal at 500 g/steer/day (500S). In addition, each steer was given daily a mineral supplement (35 g) that provided (g) Ca 4.4, P 2.8, Mg 2, Na 2, S 2.7, and (mg) Cu 0.7, Mn 420, Co 3.5, Se 0.4 and Zn 0.3.

The hay was made from a pasture consisting predominantly of carpet grass (*Axonopus affinus*), paspalum (*Paspalum dilatatum*), other native grasses (e.g. *Dicanthium*, *Andropogon*, *Aristida* and *Digitaria* spp.) with some adventive and sown legumes (*Glycine* spp, *Aeschynomene falcata*). The N content of the hay was 8.6 ± 0.9 g/kg DM with a digestibility (DM) of $45 \pm 5.2\%$.

Supplements

Cottonseed meal was manufactured by Cargil Oilseeds (Aust.) by a pre-press solvent extraction process and copra meal was manufactured by W.R. Carpenter (Agriculture) at Rabaul, Papua New Guinea by expeller extraction of oil from copra. The chemical composition of the meals is listed in table 1. Urea was a commercial fertiliser grade (460 g N/kg).

Hay was chaffed into mean lengths of 32 ± 5.2 mm. Three batches (140 kg/batch) were

TABLE 1. CHEMICAL COMPOSITION OF COPRA MEAL PELLETS AND COTTONSEED MEAL (G/KG AS FED)

	Copra meal	Cottonseed meal
Dry matter	896	908
Acid detergent fibre	332	409
Nitrogen	34	61
Ether extracts	69	12
Minerals		
Mg	3.6	6.8
S	2.6	42
K	20	15.5
P	5	9.5
Ca	0.6	2.3
Na	0.5	0.3

sprayed with a sufficient volume of a urea solution (120 g/L) to deliver 30 g urea/kg (air dry) forage and allowed to dry in the sun. Drying time was within the range of 20-40 min. The difference between sprayed and unsprayed hay in N content was used to measure urea attachment. Urea offered to a steer was estimated from the urea content of the hay and the quantity of the sprayed-hay fed; the mean intake was 22 ± 2.9 g/steer/day in the 30U treatment and 22 ± 3.0 g/steer/day in the 500C.U treatment.

Hay was offered at 08:30 h and 11:30 h based on the previous day's residue for each steer, such that the daily offering was 1.15 of that consumed. Hay residue was removed by 08:00 h each morning and bulked for each steer over 7 days which was the length of feeding periods. The mineral supplement was sprinkled on top of the 08:30 h hay offering, and protein meal supplements were given in containers separate from the hay at 09:30 h and 12:30 h daily.

Recordings

Water intake was estimated from daily recordings of meters to individual troughs. Steers were weighed at the start of the 10-day presupplementation period before the 08:30 h feeding (allocation liveweight) and then every 7-days at the start of each feeding period in the experiment. Rumen samples (30 ml) were taken *per os* on the final day of the experiment prior to the morning feeding, placed in a container with 0.5 ml of 18 M

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H₂SO₄ and centrifuged at 3000 g. The supernatant fluid was decanted and stored at -15°C before analysis. Blood samples were also taken on the final day of the experiment (day 42 supplementation) from the coccygeal vein. The samples were centrifuged and the plasma was removed and stored at -15°C. Nylon bag estimates of the disappearance of N from both copra meal and cottonseed meal were made in a ruminally fistulated steer at pasture, using the procedure described by Hennessy *et al.* (1983a). Degradability of N was calculated using the equations of Ørskov and McDonald (1979) and assuming a fractional clearance rate of 0.0667/h, which was established for mordanted protein meals for cattle on native pasture diets (Hennessy *et al.*, 1983a).

Laboratory analysis

Hay and meal samples were ground through a 1 mm sieve and digested in a micro-Kjeldahl unit with a selenium catalyst, for colorimetric analyses of N (Havilah *et al.*, 1977), and phosphorus (Simonsen *et al.*, 1946). Acid detergent fibre content on meals was determined by the technique of Goering and Van Soest (1970), and lipids by ether extract. Minerals were determined by a infra red spectrophotometer. Digestibility was determined on the ground samples of the meals and hay by an *in vitro* technique (Alexander and McGowan, 1961) and estimates made of their metabolisable

energy (ME) content (MAFF, 1975).

Plasma urea N was determined on an Auto Analyzer (Mark II, Technicon Equipment Co., New Jersey, U.S.A.) using a diacetyl monoxime technique (Marsh *et al.*, 1965) and ammonia in rumen samples by a dichloroisocyanurate technique (Havilah *et al.*, 1977) using a spectrophotometer (Shimadzu UV 240). The concentration of volatile fatty acids (VFA), and their molar proportions in 0.1 ml fluid, were measured on a Packard (Model 427, Packard Instrument Co., U.S.A.) single-column gas liquid chromatograph using 4-methyl valeric acid as an internal standard.

Statistical analysis

All data were analysed according to the generalised linear model of Nelder and Wedderburn (1972) in the programme GENSTAT (Alvey *et al.*, 1980). Liveweight gain was analysed as liveweight change over the 42 day period of supplementation with an "allocation liveweight" (i.e. before the 10-day supplementation period) as a covariate. Hay intakes were analysed over 7 periods for individual animals with diets, periods, and diets periods as the factors. In this analysis, the degrees of freedom of the critical F values were scaled by 0.48 according to the method of Greenhouse and Geisser (1959). This adjustment allowed for a significant departure of the contrast covariates from equality. Comparisons between treatments were based on

TABLE 2. LIVELWEIGHT CHANGE, WATER INTAKE, HAY INTAKE AND FEED CONVERSION EFFICIENCY OF STEERS AS AFFECTED BY SUPPLEMENTATION¹

	Treatment ²						s.e.d.
	Basal	500C	1000C	300U	500C.U	500S	
Liveweight change (g/day)	233 ^a	548 ^{ab}	946 ^c	357 ^a	718 ^{bc}	505 ^{ab}	± 130 ^{**3}
Hay intake (g/steer/day)	5040	5310	5530	5570	5630	5180	± 480
(g/kg LW/day)	20.0 ^a	21.8 ^b	20.0 ^a	21.4 ^b	21.4 ^b	20.4 ^a	± 0.75*
Water intake (L/steer/day)	16 ^a	20 ^b	20 ^b	17 ^a	20 ^b	19 ^{ab}	± 0.97**
Feed conversion efficiency (g DMI/g LW.C)	18.6 ^b	10.4 ^a	6.0 ^a	9.4 ^a	8.3 ^a	11.5 ^a	± 2.30*

¹ Means within rows with different superscripts differ.

² See text p.78.

³ *P < 0.05; **P < 0.01

TABLE 3. NITROGEN INTAKE, RUMEN AMMONIA AND VOLATILE FATTY ACID CONCENTRATIONS (VFA) OF STEERS OFFERED SUPPLEMENTS ON A LOW QUALITY PASTURE HAY

		Treatment						s.e.d
		Basal	500C	1000C	30U	500C.U	500S	
N offered (g/head/d)	Hay	42	44	46	47	47	43	
	Urea	0	0	0	10	10	0	
	Meal	0	16	32	0	16	27	
	Total	42	60	78	57	73	70	
N intake (g/head/day)		42	60	78	54	70	68	
Rumen ammonia (mg N/L)		27 ^{ab}	25 ^a	27 ^{ab}	36 ^{ab}	37 ^{bc}	38 ^{bc}	4.9*
Rumen VFA (mmol/L)		73	85	81	86	81	83	4.4
Plasma urea (mg N/L)		47 ^a	63 ^{ab}	72 ^{ab}	59 ^a	59 ^a	91 ^b	13.9*

*Means within a row with different superscripts differ ($P < 0.05$).

orthogonal contrasts and are indicated as differing from each other by letter superscripts in tables 2 and 3.

Results

Feed intake and liveweight change (LWC)

Copra meal, at a kilogram per day, or at 500 g/day with urea, significantly ($P < 0.01$) increased liveweight gain of steers on the low N forage over 42 days (figure 1) whereas 30U, 500S and 500C did not increase gain significantly (table 2). Each of the five supplements apparently increased hay intake/steer by from 2.8 to 11.7% but none of these increases was significant (table 2). However, per unit liveweight, 30U and 500C increased ($P < 0.05$) hay intake by 7.7%. All supplements significantly ($P < 0.05$) improved feed conversion efficiency by reducing the ratio (kg DM intake/kg LWC) from 18.6 to 6.0-11.5; the lowest ratio occurring in steers given the 1000C treatment. The apparent efficiency of use of copra meal at 1 kg/day (1000C) was 71.3% (i.e. 71.3 g gain/100 g meal) and at 500 g/day (500C) was 63%; with urea, the apparent efficiency was higher at 97% (500C.U).

With the exception of 30U all supplements increased ($P < 0.01$) daily water intake of the steers (table 2).

Rumen ammonia and volatile fatty acids

Rumen ammonia concentrations at day 42 were low in steers given the basal diet and in those steers supplemented with only copra meal (table 3). By comparison, steers given 500S or 500C.U diets had significantly ($P < 0.05$) higher rumen ammonia concentrations. Plasma urea N was increased ($P < 0.05$) only by cottonseed meal supplementation (500S) although there was a

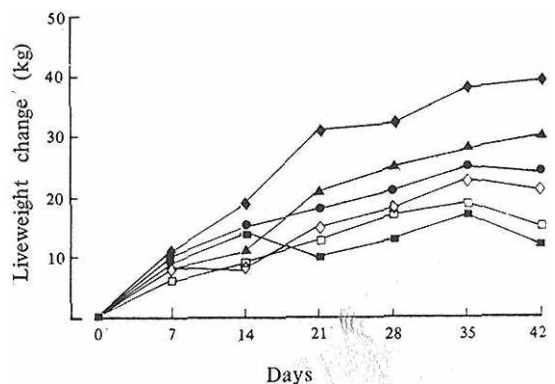


Figure 1. Cumulative liveweight change of steers on the basal hay diet and supplemented with nil, urea, copra meal or cottonseed meal as
 ■ basal, ● 500C, ◆ 1000C, □ 30U, ▲ 500C.U, ◇ 500S.

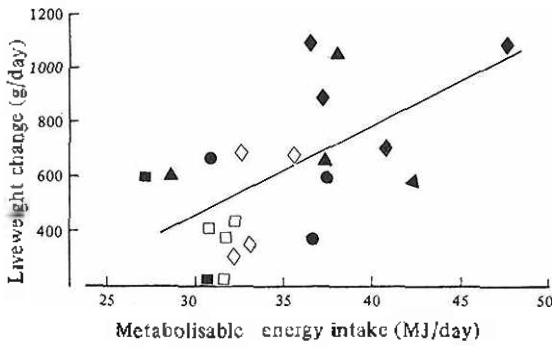


Figure 2. Liveweight change of steers over 42 days on native grass hay and supplements, and their total metabolisable energy intake from each treatment group.

■ basal, ● 500C, ◆ 1000C, □ 30U,
▲ 500C.U, ◇ 500S.

trend for higher concentrations in steers supplemented with copra meal (table 3). Rumen VFA were within the range 73-86 m mol/l with supplements having no significant effect on the concentrations or the molar proportions of the acids. The mean molar proportions (%) of the acids were 74 ± 0.8 , 15 ± 0.5 , 9 ± 0.4 and 0.5 ± 0.04 (mean \pm s.e.), respectively, for acetic, propionic, n-butyric and n-valeric acid.

Nitrogen loss from meals and rumen degradability

Copra meal DM was removed at an apparently faster rate from nylon bags in the rumen than was the DM from CSM (0.0376 vs 0.0202/h) but the N component of copra meal was more resistant to removal than was the N from CSM. The rate constants for N removal were 0.0224/h and 0.0276/h for copra meal N and CSM N respectively, and the estimates of the effective degradability at 15 h were 29% and 37% respectively for the nitrogen in copra meal and CSM.

Discussion

Supplementation of steers offered a low N native pasture hay with 1 kg copra meal/head/day increased substantially by 300% their liveweight gain. Similarly, supplementation of steers with only 500 g/head/day of copra meal, in the presence of urea, increased their liveweight gain by 200%. By comparison, supplementation of steers

with either urea or 500 g/head/day of copra meal or cottonseed meal did not elicit significant gains in liveweight. This finding differs, in part, from other studies from this centre in which 600 g cottonseed meal/head/day significantly increased liveweight of steers (Hennessy *et al.*, 1983b) and 15 g urea/head/day also increased steer liveweight (Hennessy and Williamson, 1989). However, in the present study, liveweight change of steers on the basal diet (233 g/head/day) is apparently higher than was the case in the other reports (35 and -650 g/head/day, respectively), suggesting a higher quality basal diet due to the presence of legumes which we presume reduces the need for supplemental N.

In spite of the legume presence, rumen ammonia concentrations were low in steers on the basal diet (27 mg N/L) and even though these increased with cottonseed meal supplementation, and with urea and copra meal (38, 37 mg N/L respectively), they were lower than the 50-80 mg N/L concentrations suggested (Satter and Slyter, 1974) as necessary to maximise microbial protein synthesis. It is important to raise rumen ammonia concentrations in order to increase rumen digestion rates (Hunter and Siebert, 1985) and feed intake (Boniface *et al.*, 1986). Inexplicably in this study, 500 g copra meal/day increased feed intake/kg liveweight but not rumen ammonia concentration whereas the converse occurred with 500 g/day of cottonseed meal. However, the samples of rumen fluid were taken early in the morning before the steers were fed and it is likely that ammonia concentrations were at their lowest point at this sampling time (Playne and Kennedy, 1976). Consequently, we have presumed that ammonia concentrations matched the microbial requirements for most of the day at least for steers supplemented with urea, cottonseed meal and copra meal with urea, but perhaps not for steers supplemented only with copra meal.

The finding of the low rumen ammonia concentrations in cattle supplemented with copra meal, together with the estimate of low rumen degradability, indicate that copra meal is well protected against proteolysis in the rumen. Part of the reason for this high level of protection might be the high level of oil (69 g/kg) compared with the small proportion (12 g/kg) in cottonseed meal in which the proteins appears less protected. Davenport *et al.* (1987) reported that physically coating soyabean

meal with oil reduced proteolysis.

Copra meal has only 56% of the total N of CSM but may have an advantage over cottonseed meal as a dietary supplement by enhancing the amounts of particular amino acids in the intestinal digesta due to a greater rumen protection of the copra meal proteins. Copra meal has higher digestibility coefficients of lysine and methionine in the small intestine (0.78, 0.94; respectively) than does cottonseed meal (0.53, 0.65; Hvelplund and Hesselholt, 1987). These two amino acids may limit growth of cattle on low N forages when supplemented with cottonseed meal (Lindsay *et al.*, 1988). In addition to this, coconut oil is toxic to protozoa (Newbold and Chamberlain, 1988) and the reduction in their numbers in the rumen could improve bacterial protein synthesis (Ikwuegbu and Sutton, 1982) and together with removal of protozoa from the rumen would improve the supply of nutrients to the host (Bird and Leng, 1984) when the dietary protein supplement is highly resistant to rumen degradation. Nonetheless, only CSM raised significantly the plasma urea nitrogen content which amongst other metabolic advantages, indicates a higher urea synthesis rate (Hennessy and Nolan, 1988). The higher oil and lipid content of copra meal may have other advantages. For example, the metabolic role of the lipids is inextricably involved with glucose, and glucose synthesis rate is related to liveweight change (Kempton *et al.*, 1978; Hennessy *et al.*, 1983). Lee *et al.* (1987) concluded that the majority of amino acids absorbed from a protein meal in supplemented steers was used to synthesise glucose. When ruminants mobilise body fat, or absorb long chain fatty acids, as lipids, the need for glucose is lessened (Preston and Leng, 1987). Consequently, the higher lipid content of the copra meal may have an ameliorating effect on amino acids for glucose synthesis, allowing for enhanced protein synthesis in the extra growth of the steers supplemented with the meal. Garrett *et al.* (1976) found that the efficiency of metabolisable energy use for energy deposition was increased by 20% when vegetable oil was encapsulated with a protected protein supplement in fattening beef steers. When nutrients are in short supply for high producing ruminants, lipid reserves are mobilised and non-esterified fatty acids oxidised as a means of maintaining production by preserving limited supplies of key nutrients such as

glucose and amino acids (Peel and Bauman, 1987).

Copra meal, at least in the pelleted form used in this study, is apparently well protected against proteolysis and degradation in the rumen. In previous studies (Hennessy *et al.*, 1981; 1983; and 1988b), it was postulated that an increase in non degraded proteins passing from the rumen stimulated intake of the basal hay diet. Liveweight then responded to the additional metabolisable energy available from the extra hay and the supplement. The results from this study support this postulation, since liveweight change and estimated ME intake were correlated ($r = 0.64$; $P < 0.01$) for steers over 42 days (figure 2). However, the results are somewhat equivocal for supporting the hypothesis that higher rumen ammonia concentrations, up to 70 mg N/L (Elliott *et al.*, 1984) in sheep, and up to 140 mg N/L (Boniface *et al.*, 1986) in cattle, support higher feed intakes. Nonetheless, the results emphasise the importance of higher hay intakes with the supplements in increasing liveweights. We suggest therefore that at least with moderate feeding rates, urea should be included with copra meal as a supplement to ensure high rumen nitrogen availability and maintain high intake of forage. This combination would be a useful and appropriate supplement to maintain cattle liveweights on the low N, low digestible forages, in tropical Australia and the Pacific nations and would have a price advantage over cottonseed meal in these areas. Higher rates of feeding might be required to improve the conception rate of lactating cattle and the economic benefits of doing this require study.

Acknowledgements

We thank Mr. A. Martin for the care and feeding of the animals and Messrs. F. Ball (University of New England) and G. Rose (North Coast Agricultural Institute) for the laboratory analyses. Statistical analysis of the data was done by Mr. R. Darnell, and by Miss. C. Wilson. The NSW Agriculture & Fisheries provided the animals, facilities and the staff, assisted by a financial contribution from W.R. Carpenter (Agriculture), Perth, Western Australia.

Literature Cited

Ajvey, N.G. and 17 others. 1980. GENSTAT. A General

- Statistical Program. Numerical Algorithms Group Ltd., Oxford, U.K.
- Alexander, R.H. and M. McGowan. 1961. A filtration procedure for the *in vitro* determination of digestibility of herbage. *Journal of British Grassland Society* 16: 275.
- Bird, S.H. and R.A. Leng. 1984. Further studies on the effects of the presence or absence of protozoa in the rumen on live-weight gain and wool growth of sheep. *British Journal of Nutrition* 52:607.
- Boniface, A.N., R.M. Murray and J.P. Hogar. 1986. Optimum level of ammonia in the rumen liquor of cattle fed tropical pasture hay. *Proceedings of the Australian Society Animal Production* 16:151.
- Davenport, G.M., J.A. Boling, N. Gay and L.D. Buating. 1987. Effect of soybean lipid on growth and ruminal nitrogen metabolism in cattle fed soybean meal or ground whole soybeans. *Journal of Animal Science* 65:1680.
- Ellicott, R., N.P. McMeniman, B.W. Norton and F.J. Calderon Cortez. 1984. The food intake response of sheep fed five roughage sources supplemented with formaldehyde-treated casein with and without urea. *Proceedings of the Australian Society of Animal Production* 15:337.
- Garrett, W.N., Y.T. Yang, W.L. Dunkley and I.M. Smith. 1976. Energy utilization, feed lot performance and fatty acid composition of beef steers fed protein encapsulated tallow or vegetable oils. *Journal of Animal Science* 42:1522.
- Goering, H.K. and P.J. Van Soest. 1970. Forage Fiber Analyses. *Agriculture Handbook No. 379*. United States Dept. Agriculture.
- Greenhouse, S.W. and S. Geisser. 1959. On methods in the analysis of profile data. *Psychometrika* 24:95.
- Havilah, E.J., D.M. Wallis, R. Morris and J.A. Woolnough. 1977. A micro colorimetric method for determination of ammonia in Kjeldahl digests with a manual spectrophotometer. *Laboratory Practice* 26:545.
- Hennessy, D.W., G.J. Lee and P.J. Williamson. 1983. Nitrogen loss from protein meals held in terylene bags in the rumen of cattle and the nutritive value of the residues. *Australian Journal of Agricultural Research* 34:453.
- Hennessy, D.W. and J.V. Nolan. 1988. Nitrogen kinetics in cattle fed a mature sub-tropical grass hay with and without protein meal supplementation. *Australian Journal of Agricultural Research* 39:1135.
- Hennessy, D.W., P.J. Williamson, R.F. Lowe and D.R. Baigent. 1981. The role of protein supplements in nutrition of young grazing cattle and their subsequent productivity. *Journal of Agricultural Science Cambridge* 96:205.
- Hennessy, D.W., P.J. Williamson, J.V. Nolan, T.J. Kempton and R.A. Leng. 1983. The roles of energy- or protein-rich supplements in the subtropics for young cattle consuming basal diets that are low in digestible energy and protein. *Journal of Agricultural Science Cambridge* 100:657.
- Hennessy, D.W. and P.J. Williamson. 1988a. Effects of protein meal supplements on the growth and reproduction of Hereford heifers and cows grazing a native grass pasture in the subtropics. *Australian Journal of Experimental Agriculture* 28:439.
- Hennessy, D.W. and P.J. Williamson. 1988b. A comparison of cottonseed and formaldehyde-treated sunflower meals on the production of *Bos indicus* and *Bos taurus* cattle on subtropical pasture hay. *Asian-Australasian Journal of Animal Science* 1:107.
- Hennessy, D.W. and P.J. Williamson. 1989. Feed intake and liveweight of cattle on subtropical native pasture hays 1. The effect of urea on cattle production. *Australian Journal of Agricultural Research* (submitted).
- Hunter, R.A. and B.D. Siebert. 1980. The utilization of Spear Grass (*Heteropogon contortus*) iv. The nature and flow of digesta in cattle fed on spear grass alone and with protein or nitrogen or sulfur. *Australian Journal of Agricultural Research* 31:1037.
- Hunter, R.A. and B.D. Siebert. 1985. Utilization of low quality roughage by *Bos taurus* and *Bos indicus* cattle 1. Rumen digestion. *British Journal of Nutrition* 53:637.
- Hvelplund, T. and M. Hesselholt. 1987. Digestibility of individual amino acids in rumen microbial protein and undegraded dietary protein in the small intestine of sheep. *Acta Agriculturae Scandinavica* 37:469.
- Ikweghbu, O.A. and J.D. Sutton. 1982. The effect of varying the amount of linseed oil supplementation on rumen metabolism in sheep. *British Journal of Nutrition* 48:365.
- Kempton, T.J., G.H. Smith and R.A. Leng. 1978. The relationship between growth and glucose availability in sheep and cattle. *Proceedings of the Australian Society Animal Production* 12:139.
- Lee, G.J., D.W. Hennessy, J.V. Nolan and R.A. Leng. 1987. Responses to nitrogen and maize supplements by young cattle offered a low quality pasture hay. *Australian Journal of Agricultural Research* 38:195.
- Lindsay, J.A., G.W.J. Mason and M.A. Toleman. 1982. Supplementation of pregnant cows with protected proteins when fed tropical forage diets. *Proceedings of the Australian Society Animal Production* 14:67.
- Lindsay, J.A., J.F. Kidd, M. Cervoni and D.J. Reid. 1988. Rumen protected amino acids as supplements for growing steers offered low quality roughage diets. *Proceedings of the Australian Society of Animal Production* 17:431.
- MAFF. 1975. Energy Allowances and Feeding Systems for Ruminants. Technical Bulletin 33, Ministry of Agriculture, Fisheries and Food, H.M.S.O., London.
- Marsh, W.H., B. Fingerhut and H. Miller. 1965. Automated and manual direct methods for determination of blood urea. *Clinical Chemistry* 11:624.
- Neider, J.A. and R.W.N. Wedderburn. 1972. Generalised linear models. *Journal of the Royal Statistical Society, A*. 135:370.
- Newbold, C.J. and D.G. Chamberlain. 1988. Lipids as rumen-defaunating agents: *Proceedings of the*

- Nutrition Society 47:154A.
- Ørskov, E.R. and I. McDonald. 1979. The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. *Journal of Agricultural Science Cambridge* 92:499.
- Peel, C.J. and D.E. Bauman. 1987. Somatotropin and lactation. *Journal of Dairy Science* 70:474.
- Playne, M.J. and P.M. Kennedy. 1976. Ruminant volatile fatty acids and ammonia in cattle grazing dry tropical pastures. *Journal of Agricultural Science Cambridge* 86:367.
- Preston, T.R. and R.A. Leng. 1987. Matching Ruminant Production Systems with Available Resources in the Tropics and Sub-tropics (pp. 67-81). Penambul Books: Armidale, Australia.
- Satter, L.D. and L.L. Slyter. 1974. Effect of ammonia concentration on rumen microbial protein production *in vitro*. *British Journal of Nutrition* 32:199.
- Simonsen, D.G., M. Wertman, L.M. Westover and J.W. Mehl. 1946. The determination of serum phosphate by the molybdovanadate method. *Journal of Biological Chemistry* 166:747.
- Winks, L.W. 1984. Cattle growth in the dry tropics of Australia. Australian Meat Research Committee Review No. 45.