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Effects of supplement type and previous experience on variability in intake of supplements by heifers

R. M. Dixon[A,B,E], *A. White*[A,C], *P. Fry*[A,D], *and J. C. Petherick*[A,B]

[A]Agency for Food and Fibre Sciences, QBII, Swan's Lagoon Research Station, Millaroo, Ayr, Qld 4807, Australia.
[B]Present address: Agency for Food and Fibre Sciences, QBII, Parkhurst, PO Box 6014, Rockhampton, Qld 4702, Australia.
[C]Present address: MS 221, Bauple, Qld 4650, Australia.
[D]Present address: Agency for Food and Fibre Sciences, QBII, Department of Primary Industries, PO Box 976, Charters Towers, Qld 4820, Australia.
[E]Corresponding author; email: rob.dixon@dpi.qld.gov.au

Abstract. Intakes, and variability in intakes, of a range of supplements were examined in groups (n = 10–20) of cattle grazing tropical native pasture in 24-ha paddocks. Intakes of supplement by individual animals were measured using lithium sulfate as a marker. In Expt 1, heifers (n = 160) were offered 1 of 4 supplements consisting of (*i*) a restricted amount of cottonseed meal (CSM); or *ad libitum* amounts of (*ii*) molasses containing 74 g urea/kg (M8U), (*iii*) a loose mineral mix (LMM) containing (g/kg) salt 390, urea 300, CSM 150, calcium phosphate 150, and sulfur 10, and (*iv*) feed block supplements containing (g/kg) molasses 494, urea 99, calcium phosphate 62, salt 62, bran 62, calcium oxide 148, and magnesium oxide 74. After 5 and 10 weeks the variation in supplement intake among heifers within a group was lower ($P < 0.05$) for CSM and M8U (coefficient of variation (CV) 24–37%) than for the LMM or block supplements (CV 55–118%). All heifers offered CSM or M8U consumed at least some supplement, but up to 5% and 20% of heifers were non-eaters of LMM or block supplement, respectively. Both the per cent non-eaters of supplement and the variability in intake of these latter supplements tended ($P < 0.10$) to decline as the experiment progressed. In Expt 2 the same heifers were re-allocated to paddock groups and were offered *ad libitum* supplements of (*i*) M8U, (*ii*) molasses containing 107 g urea/kg (M12U), (*iii*) M8U mixed with monensin (M8U-M), or (*iv*) M8U mixed with meatmeal (M8U-MM). The CV of supplement intake ranged from 37 to 58%, and except in one paddock group offered M8U-MM, all heifers consumed at least some supplement. In Expt 3, paddock groups of heifers (n = 120) without or with experience of LMM supplements during the previous dry season were offered LMM supplements containing either nil or 300 g CSM/kg. Voluntary intake of LMM supplement DM was increased ($P < 0.001$) by 93% by inclusion of CSM and decreased ($P < 0.05$) by 24% by previous experience of a similar LMM supplement. Neither variability in supplement intake (CV 66–150%) nor the per cent non-eaters was significantly ($P > 0.05$) affected by previous experience of the heifers with LMM supplements or inclusion of CSM in the supplement. However, the per cent non-eaters of LMM supplement was inversely related to the mean voluntary intake of the supplement by the paddock group; when the average voluntary intake of the supplement by the paddock group exceeded 0.2 g DM/kg LW.day, then ≤10% of heifers were non-eaters of supplement. In conclusion, within groups of heifers offered LMM and block supplements the variability in intake and per cent non-eaters of supplement were higher than for cottonseed meal or molasses-urea supplements, and variability appeared to be associated with voluntary intake of the supplements.

Additional keywords: cattle, lithium marker, supplement intake, variability in intake.

Introduction

Production of grazing ruminants is often constrained during at least some seasons by low concentrations of essential nutrients in forage. For example, in the seasonally dry tropics of northern Australia, the Americas, and Africa, forages are often low in digestibility and contain inadequate concentrations of nitrogen, phosphorus, sulfur, and sodium for at least part of the annual cycle (Little 1982; McDowell *et al.* 1984; Winks 1984). Supplements are often provided to grazing ruminants to alleviate such inadequacies but their

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efficacy and cost-effectiveness are often reduced by the difficulties of achieving target intakes of supplement by all animals in the herd (Bowman and Sowell 1997).

Supplements are usually provided to grazing ruminants either as readily acceptable concentrates offered infrequently in discrete meals, or *ad libitum* but where voluntary intake of the supplement is constrained by characteristics of the supplement or the supplement delivery system. The effects of previous experience and of the delivery system on intakes of grain and protein meal supplements by individual animals have been investigated (Arnold and Bush 1968; Arnold and Maller 1974; Chapple and Lynch 1986; Holst *et al.* 1994; Kahn 1994; Dixon *et al.* 2001). However, there is little information on the factors influencing intakes by individual animals of supplements such as molasses-urea, loose mineral mixes (LMM), and solidified feed blocks offered *ad libitum*. Studies where cattle have been offered supplements as blocks (Murray *et al.* 1978; Eggington *et al.* 1990), molasses-urea (Nolan *et al.* 1974; Bowman and Sowell 1997; Dixon and Smith 2000), or LMM (Dixon *et al.* 2000, 2001) have shown that a substantial proportion of a herd may not consume any supplement, and amongst animals that do consume supplement the variability in supplement intake may be high. Variability in intake of LMM and block supplements by cattle appears to be higher than for supplements based on grain and protein meals (Kendall *et al.* 1980*a*; Dixon *et al.* 2001). Similar results have been reported for sheep (Nolan *et al.* 1975; Lobato *et al.* 1980; Ducker *et al.* 1981; Kendall *et al.* 1983). However, since most of these experiments examined a single supplement delivery system and type of supplement it is difficult to draw general conclusions on the factors influencing supplement intakes by individual animals in herds.

To improve supplement delivery systems it is clearly necessary to understand the factors influencing intakes of supplement by individual animals. The following experiments were undertaken to investigate the factors determining the proportion of non-eaters of supplement and the variability among animals in supplement intake by grazing cattle in a seasonally dry tropical environment. Expt 1 compared supplements consisting of a restricted amount of protein meal or *ad libitum* amounts of 3 supplements: a molasses-urea supplement that provided substantial metabolisable energy, and non-protein nitrogen supplements provided as LMM or a solidified feed block. Expt 2 compared 4 molasses supplements, each of which provided substantial amounts of metabolisable energy. Expt 3 examined the consequences of modifying an LMM supplement by inclusion of cottonseed meal (CSM) and/or prolonged previous exposure of the cattle to a similar supplement on the voluntary intake of supplementary nutrients. Small herds of cattle grazing small paddocks were used in the experiments to allow replication of treatments. In one experiment, meatmeal was included as a component of a molasses-based supplement. When the studies reported herein were conducted there were no legal constraints either in Australia or in most other countries to its use as a feedstuff and we wished to investigate evidence that inclusion of meatmeal in supplements increased variability among animals in supplement intake.

Materials and methods

General

The experiments were carried out at the Swan's Lagoon Research Station situated 100 km SSE of Townsville in the dry tropics of northern Australia. At this site the distribution of rainfall is highly seasonal with about 75% of the annual average of 880 mm occurring from December to March; the consequences for growth and quality of pasture and cattle growth have been described by Winks (1984). *Bos indicus* × *Bos taurus* (>F_2) heifers from the station herd were used in the experiments. This herd had been genetically closed for 2 decades, with selection and management such that the cattle were generally of docile temperament and were accustomed to mustering and handling. The pastures comprised tropical grasses native or naturalised to the open eucalyptus woodlands of the speargrass region of coastal north-eastern Australia. Major grass species were black speargrass (*Heteropogon contortus*) with other tropical tall grasses and medium grasses including *Chrysopogon fallax* and *Bothriochloa pertusa*.

Expt 1

Heifers ($n = 160$), initially 17–20 months of age, mean liveweight (LW) 260 kg (s.d. 32 kg) and mean body condition score (CS) 5.8 (range 5–7) on a 9-point scale (NRC 1996) were used. The heifers were derived from 2 herds of breeders (Herds A and B) on the research station. The heifers from each breeder herd had been managed separately following weaning. All heifers had been offered molasses-CSM-urea supplements for 1–2 weeks while held in yards immediately following weaning at 3–6 months of age and early in the dry season. The heifers ($n = 72$) from Herd B had not been given any other supplements. However, the heifers ($n = 88$) from Herd A had also been offered a supplement of molasses containing 74 g urea/kg (M8U) for 5 months during the dry season following weaning; intake of this supplement averaged 0.3 kg/head.day and these heifers were on average 29 kg heavier ($P < 0.01$) at the commencement of the experiment. In Expt 1, measurements were made in all heifers from 10 June 1994 early in the dry season to the 27 September 1994 (Phase 1), and also in some heifers from the 2 November 1994 to the 4 April 1995 (Phase 2). From 27 September 1994 until the 2 November 1994, all of the heifers were used for Expt 2 described below.

At the commencement of Phase 1 the heifers were mustered, weighed, and allocated by stratified randomisation based on the herd of origin and LW to 8 groups ($n = 20$; 11 and 9 originating from Herds A and B, respectively), which were then allocated randomly to eight 24-ha paddocks. The pasture initially offered in these paddocks was estimated visually to exceed 2 t dry matter (DM)/ha. For Phase 2 of Expt 1, 2 paddock groups of heifers given a specific treatment during Phase 1 were, on the 2 November 1994, returned to the same paddock groups and given the same supplement treatment as during Phase 1. During Phase 2, each group of heifers initially grazed a 24-ha paddock, but from the 1 December 1994 each group had access to two 24-ha paddocks. Each group of heifers was joined with 2 bulls from the 20 December 1994 until the end of Phase 2. Thus, in Expt 1, measurements were made from 10 June to 27 September 1994, and later from the 2 November 1994 to 4 April 1995.

There were 4 supplementation treatments as follows: (*i*) CSM equivalent to 0.5 kg air-dry/heifer.day was offered in 2 equal amounts twice weekly; (*ii*) M8U; (*iii*) loose mineral mix (LMM); (*iv*) solidified feed blocks (Blocks). The M8U, LMM, and Block supplements were offered *ad libitum*. The 8 paddock groups were allocated to the 4 treatments in a randomised block experimental design; the 8 paddocks were divided into 2 blocks on the basis of position and soil type. All supplements were offered from 22 July 1994 until 27 September 1994 (i.e. Phase 1). The LMM supplement mixture offered during Phase 1 was also provided *ad libitum* from 11 November 1994 until the 26 December 1994 (i.e. Weeks 16–22) when the wet season commenced. A different LMM supplement mixture was offered from the 8 February 1995 until the 4 April 1995 (i.e. Weeks 29–36). Thus, LMM supplement was offered for 23 weeks during Phases 1 and 2 of Expt 1. Each of the supplements was offered in troughs placed 10 m apart and about 30 m from the only waterpoint in each paddock. CSM was offered in three 1.2 by 0.6 m troughs, the M8U and blocks in two 0.9 by 0.6 m troughs, and the LMM was offered in a single open-ended trough (2.4 by 0.5 m).

M8U was mixed in a horizontal paddle mixer, care being taken to ensure that all of the urea was dissolved. The LMM supplement offered during the dry season (i.e. during Phase 1 and from 11 November 1994 until 26 December 1994) contained (g/kg air-dry) salt 390, urea 300, CSM 150, calcium phosphate (Kynophos, Kynoch Feeds PLC, South Africa) 150, and sulfur 10, and the LMM offered during the wet season (i.e. from 8 February 1995 until 4 April 1995) contained (g/kg air-dry) CSM 373, salt 300, calcium phosphate 210, urea 100, and sulfur 7. The blocks contained (g/kg air-dry) molasses 494, urea 99, calcium phosphate 62, salt 62, bran 62, calcium oxide 148, and magnesium oxide 74 and were allowed to set in moulds following mixing. Fresh LMM supplements were offered twice each week, on each occasion the residues being removed, weighed, and subsampled for DM content. The amounts of M8U and block supplements remaining were measured twice weekly, and additional supplement was offered when necessary to allow *ad libitum* intake. There were no refusals of CSM. Weekly intake of supplement was calculated for each paddock group from these data.

Lithium was used as a marker (Suharyono 1992; Dixon *et al.* 2003) to measure intake of supplement by each animal in each paddock group on 2 or 3 occasions. Lithium sulfate monohydrate was mixed with the supplements offered between 0700 and 1630 hours on one day after 5 and 10 weeks of supplementation, and also for the LMM supplement 36 weeks after the experiment commenced. Lithium-labelled CSM was prepared by spraying an aqueous solution of lithium sulfate over the CSM (140 mg Li/kg supplement) while it was being mixed in a horizontal paddle mixer, and lithium-labelled M8U was prepared by mixing an aqueous solution of lithium sulfate with the M8U (140 mg Li/kg supplement). Lithium-labelled LMM and lithium-labelled blocks were prepared by thoroughly mixing the lithium sulfate (2.5–5.6 g Li/kg supplement) with the ingredients during preparation. The amounts of lithium sulfate added were intended to provide approximately 1 mg Li/kg LW. On the day following provision of lithium-labelled supplements the cattle were mustered commencing at 0700 hours and, before access to water, weighed and blood sampled from the jugular vein using vacutainers containing potassium EDTA as an anti-coagulant. Samples were immediately chilled in iced water and centrifuged (3000*G* for 10 min) to separate plasma, and the plasma was stored frozen.

Expt 2

The 160 heifers used in Expt 1 were, on the 27 September 1994, re-allocated by stratified randomisation based on herd of origin, treatment in Expt 1, and LW to 8 groups (n = 20). The mean LW was 274 (s.d. 31) and 245 (s.d. 21) kg for the heifers of Herd A and Herd B origin, respectively. These 8 groups of heifers were allocated randomly to the 24-ha paddocks used for Expt 1, and commencing on the 10 October 1994, 1 of 4 molasses supplements was provided for 3 weeks. The 8 paddocks were allocated to the 4 supplement treatments in a randomised block experimental design. The supplements consisted of the following mixtures: (*i*) M8U as described for Expt 1; (*ii*) molasses containing 107 g urea/kg (M12U); (*iii*) M8U containing monensin (Rumensin Premix, Elanco Animal Health, West Ryde, NSW) at the concentration of 120 mg monensin/kg during Weeks 1 and 2, and 180 mg monensin/kg during Week 3 (M8U-M); and (*iv*) M8U mixed with meatmeal at levels of 25 g/kg during Week 1, 50 g/kg during Week 2, and 100 g/kg during Week 3 (M8U-MM). Concentrations of monensin and meatmeal were increased progressively through the experiment to attempt to maintain similar voluntary intake of supplement in each week. Supplements were provided *ad libitum* in two 0.9 by 0.6 m troughs 10 m apart sited approximately 30 m from the water trough. Supplement intake by each paddock group was calculated from twice weekly measurements of supplement disappearance. Supplement offered and refused was subsampled each week for measurement of DM content. Lithium-labelled supplement (170 mg Li/kg M8U and 240–380 mg Li/kg for the other supplements) intended to provide approximately 1 mg Li/kg LW was offered between 0815 and 1630 hours on one day after 3 weeks; on the following day the cattle were mustered, weighed, and blood sampled as described for Expt 1 to provide a measurement on one occasion of supplement intake by individual heifers.

Expt 3

Heifers (n = 120), initially 15–18 months of age, with 2 regimes of previous experience of supplements were used in this experiment. All of the heifers had been offered molasses-based supplements for 1–2 weeks while held in yards immediately following weaning about 9 months before the experiment commenced on 19 January 1996. Sixty heifers had no other experience of supplements (‘naive’ treatment heifers), whereas the remaining heifers had, in addition, been offered LMM supplement containing 300 g urea/kg for 6 months during the dry season prior to the experiment as described by Dixon *et al.* (2001) (‘experienced’ treatment heifers). The initial LW and CS of the experienced and naive groups of heifers were 217 (s.d. 16) and 215 (s.d. 16) kg, and CS 5.1 and 4.9 (both s.d. 0.3), respectively, and did not differ ($P > 0.05$) between groups. Within each of these 2 groups the heifers were allocated by stratified randomisation based on LW to 6 groups. Thus there were 12 groups each of 10 heifers. These 12 groups were allocated to 4 treatments in a 2 × 2 factorial arrangement using a randomised block experimental design; the 12 paddocks were the same as those used for Expts 1 and 2 and were divided into 3 blocks on the basis of position and soil type. The factors consisted of the previous regimes of experience of LMM supplements and supplementation with 2 types of LMM that included (+CSM) or did not include (–CSM) cottonseed meal. The –CSM supplement contained (g/kg as fed) 448 salt, 313 calcium phosphate, 224 urea, and 15 elemental sulfur. The +CSM supplement contained (g/kg as fed) 330 CSM, 300 salt, 210 calcium phosphate, 150 urea, and 10 elemental sulfur. Supplements were offered *ad libitum* from 7 February 1996 for 19 weeks. Fresh supplement was offered twice each week, on each occasion supplement residues being removed, weighed, and subsampled for DM content. Lithium-labelled supplement (5–10 g Li/kg of +CSM supplement and 10–20 g Li/kg of –CSM supplement) was offered between 0700 and 1630 hours on one day during Weeks 7, 11, and 17 and the heifers were mustered, weighed, and blood sampled the following day as described for Expt 1 to provide measurements on 3 occasions of supplement intake by individual heifers.

Laboratory analysis, calculations, and statistical procedures

Dry matter content of supplements was determined by oven-drying at 70°C. Plasma proteins were precipitated by addition of 1 mL plasma to 5 mL 2% trichloroacetic acid, the supernatant being separated by centrifugation (3000*G* for 10 min). Lithium concentration in the supernatant was determined using an inductively coupled plasma mass spectrometer (ICPMS). Net concentrations of lithium in plasma were calculated by subtraction of background lithium concentrations in plasma obtained from representative animals before lithium-labelled supplements were offered (16 µg Li/L in Expts 1 and 2; 7 µg/L in Expt 3). The net concentrations of lithium in plasma, the liveweight of the animals, and the total intake of lithium-labelled supplement by each paddock group were used to calculate the intakes by all individual cattle in each paddock of the consumed lithium-labelled supplement (Suharyono 1992). Non-eater animals were defined as those that consumed <1 g of lithium-labelled supplement during the interval it was provided; this generally coincided with a lithium concentration in plasma <1.5 times mean background concentration.

The results were examined using analysis of variance. Data from Expts 1 and 2 were considered as a split-plot ANOVA, the supplement treatments and paddock blocks being considered in the main plot and the herd of origin in the subplot. For Expt 2, supplement treatment offered in Phase 1 of Expt 1 was an additional split-plot factor. Results for the per cent non-eaters of supplement in groups of animals were subjected to an arcsin transformation before analysis of variance. Data from Expt 3 were considered in an ANOVA that examined the main and interaction effects of supplement type and previous experience of supplement at each of the measurement times. Where the *F* test was significant, planned comparisons between treatment means were made using the least significant difference (l.s.d.) test.

Results

Experiment 1

Rainfall from 1 November 1993 to 31 March 1994, prior to the experiment, was 750 mm, but there was no effective rainfall from mid-March until 26 December 1994 when the new wet season commenced. Thus, during Weeks 1–22 of the experiment (Phase 1 and part of Phase 2), the pastures were senesced and of low nutritive value. There was 326 mm of rain during the later part of Phase 2 from the 26 December 1994 to early April 1995.

Mean DM contents of the CSM, M8U, LMM, and block supplements were 862, 793, 968, and 873 g/kg, respectively. Intakes of the supplements measured by disappearance from the troughs in which they were offered during Weeks 1–10 (Phase 1), and for LMM supplement also during Weeks 29–36 (Phase 2), are shown in Fig. 1. All of the CSM supplement was readily consumed by the heifers and thus intake was 431 g DM/day. Voluntary intake of M8U and blocks averaged 963 g DM/day and 95 g DM/day, respectively. Voluntary intake of LMM supplement offered during Weeks 1–10 averaged 155 g DM/day. Intake of LMM supplement offered during Weeks 29 and 30 could not be measured satisfactorily due to rain washing the supplement from the troughs, but appeared to be negligible. Intake subsequently increased and averaged 76 g DM/day during Weeks 31–36. Intake of the lithium-labelled supplements offered *ad libitum* was, on average, 113% of the intake of the non-labelled supplement during the preceding 2–3 days. The lithium-labelled CSM was consumed completely. LW change during the supplementation interval was not affected ($P > 0.05$) by the herd of origin but was influenced ($P < 0.01$)

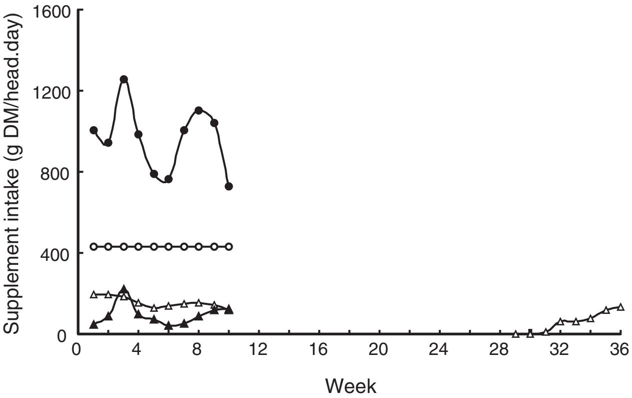

Fig. 1. Expt 1. Intakes of supplement dry matter measured by disappearance from the troughs in which it was offered when a restricted amount of cottonseed meal (CSM) (○) or *ad libitum* amounts of molasses containing 74 g urea per kg (M8U) (●), loose mineral mix (LMM) (△), or feed blocks (Blocks) (▲) were offered to groups of heifers grazing dry-season pasture. See *Materials and methods* for explanation of the treatments and phases.

by the supplements (Table 1); LW loss was greatest ($P < 0.05$) for M8U and block supplements (–0.11 and –0.12 kg/day, respectively). Heifers offered the LMM supplements were in LW maintenance (–0.01 kg/day), whereas heifers offered CSM gained LW (0.10 kg/day).

All of the heifers offered CSM or M8U consumed some of the lithium-labelled supplement (Table 1). Heifers of Herd A origin consumed more of the restricted amount of lithium-labelled CSM than did the heifers of Herd B origin (1690 and 1287 g DM, respectively, $P < 0.05$) after 10 weeks of supplementation, although there was no difference after 5 weeks. Herd of origin did not affect ($P > 0.05$) the voluntary intake or the per cent non-eaters of M8U, LMM, or block supplements after 5 or 10 weeks. After 5 weeks, 5% (2/39) of heifers were non-eaters of lithium-labelled LMM supplement, and 20% (8/40) of heifers were non-eaters of lithium-labelled block supplement. After the supplements had been fed to heifers for 10 weeks the per cent non-eater heifers was 3% and 16%, respectively, and the per cent non-eaters of the blocks tended ($P = 0.06$) to be greater than for the other supplements (Table 1). The coefficient of variation (CV) in intake of lithium-labelled supplement was influenced by supplement type after both 5 and 10 weeks of supplementation ($P < 0.05$ and $P < 0.01$), and after 10 weeks of supplementation there was an interaction ($P < 0.05$) between supplement type and herd of origin. Irrespective of the herd of origin, the CV of CSM and M8U supplements after 5 and 10 weeks was low and in the range 24–37%. After 5 weeks the CV of LMM and block supplements was 70–118% and after 10 weeks 55–92%. The interaction between supplement type and herd of origin after 10 weeks was because the CV of LMM and block intake was lower, or tended to be lower, for Herd A than Herd B heifers. On average, the CV of block intake tended ($P < 0.10$) to be

Table 1. Expt 1. Liveweight (LW), body condition score (CS), changes in LW and CS, voluntary intake of lithium-labelled supplement offered on one day, the coefficient of variation (CV%), and the per cent non-eaters of this lithium-labelled supplement

Heifers of 2 herds of origin (Herd A and Herd B) grazed 24-ha paddocks and were offered supplements of a restricted amount of cottonseed meal (CSM) or *ad libitum* amounts of molasses-urea (M8U), loose mineral mix (LMM), or feed block (block) supplements. Analysis of variance of the per cent non-eaters was carried out following an arcsin transformation of the results. The mean values for each treatment are the equivalent means as percentages; the values in parentheses are the mean (or s.e.m.) of the transformed values

Measurement	Herd A origin				Herd B origin				s. e. m.		Significance		
	CSM	M8U	LMM	Block	CSM	M8U	LMM	Block	Between herds	Between supps	Herd	Supps	Herd × supps
Initial LW (kg)	275	278	274	279	249	249	245	247	3.1	0.7	**	n.s.	n.s.
LW at Week 10 (kg)	284	268	273	269	255	243	245	238	3.0	2.2	**	*	n.s.
LW change, Week 1–10 (g/day)	120	–135	–17	–128	79	–79	–4	–102	13.0	17.0	n.s.	**	n.s.
LW at Week 36 (kg)	–	–	367	–	–	–	342	–	7.3	–	*	–	–
Initial CS	5.9	6.1	6.1	6.0	5.5	5.7	5.6	5.6	0.063	0.039	**	*	n.s.
CS at Week 10	5.4	5.3	5.2	5.1	5.2	4.9	5.0	4.8	0.043	0.052	**	n.s.	n.s.
CS change, Week 1–10	–0.5	–0.8	–0.9	–0.9	–0.3	–0.8	–0.6	–0.8	0.038	0.071	n.s.	*	n.s.
CS at Week 36	–	–	6.8	–	–	–	7.2	–	0.104	–	*	–	–
Intake of supplement (g DM)													
Week 5	1453	650	75	80	1577	612	66	85	12.1	12.3	n.s.	**	n.s.
Week 10	1690	767	60	138	1287	692	59	144	1.4	4.5	**	**	**
Week 36	–	–	84	–	–	–	117	–	26.9	–	n.s.	–	–
Non-eaters of supplement (%)													
Week 5	0	0	2	17	0	0	6	21	–	–	–	–	–
	(0.00)	(0.00)	(0.15)	(0.43)	(0.00)	(0.00)	(0.25)	(0.48)	(0.049)	(0.099)	n.s.	n.s.	n.s.
Week 10	0	0	0	13	0	0	3	16	–	–	–	–	–
	(0.00)	(0.00)	(0.00)	(0.37)	(0.00)	(0.00)	(0.17)	(0.42)	(0.30)	(0.076)	n.s.	n.s.	n.s.
Week 36	–	–	0	–	–	–	6	–	–	–	–	–	–
	–	–	(0.00)	–	–	–	(0.25)	–	(0.174)	–	n.s.	–	–
Variability of supplement intake (CV%)													
Week 5	25	24	70	92	37	35	100	118	34.4	34.4	n.s.	*	n.s.
Week 10	27	27	55	73	29	25	86	92	31.5	15.5	**	**	*
Week 36	–	–	68	–	–	–	47	–	1.7	–	n.s.	–	–

$^*P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$; n.s., not significant.

higher than for the LMM supplements (94 and 78% respectively). Also the CV of LMM and block intakes tended ($P < 0.10$) to decrease with longer experience of the animals with the supplements. The CV was 85, 71, and 57% after 5, 10, and 36 weeks, respectively, for the LMM supplement, whereas the CV was 105% and 83% after 5 and 10 weeks, respectively, for the block supplement. Intakes of lithium-labelled supplements by individual heifers after 10 weeks were correlated with the respective intakes after 5 weeks for the block, CSM, and M8U supplements ($r = 0.44$, $P < 0.001$; $r = 0.32$, $P < 0.05$; and $r = 0.25$, $P = 0.07$, respectively; $n = 40$ for each supplement). Within supplement type there was no significant relationship between intake of supplement and LW change.

Experiment 2

DM content of the supplements ranged from 776 to 786 g/kg. On average the heifers consumed 1.49 kg DM/day of the M8U supplement and 1.02–1.10 kg DM/day of the M12U, M8U+M, or M8U+MM, but intake of the various supplements did not differ significantly ($P > 0.05$; Table 2). Intake of M8U and M8U+MM supplements tended ($P = 0.05$) to increase during the experiment, despite the incremental increases in meatmeal content in the latter treatment.

Intake by the paddock groups of heifers measured by disappearance of supplement from the troughs of lithium-labelled supplement was on average only 37% of the intake of non-labelled supplement during the preceding 4 days (0.67 and 1.81 kg, respectively). Intake of lithium-labelled supplement by individual heifers was greater for Herd A than for Herd B heifers (0.58 and 0.43 kg DM, respectively, $P < 0.01$; 2.1 and 1.8 g DM/kg LW, respectively, $P < 0.05$). Also, intake was greater ($P < 0.05$) for heifers previously offered M8U during Expt 1 (0.59 kg DM or 2.3 g DM/kg LW) than the other supplements (0.45–0.49 kg DM or 1.8–1.9 g DM/kg LW). The variation in intake of lithium-labelled supplement (CV 37–58%) and the per cent non-eaters did not differ ($P > 0.05$) among the 4 molasses-based supplements (Table 2). With the exception of one paddock group offered M8U-MM where 6/20 heifers were non-eaters, all of the heifers in these groups consumed supplement.

Table 2. Expt 2. Intakes of supplement dry matter, the coefficient of variation (CV%) of intake of lithium-labelled supplement by individual heifers, and the per cent non-eater heifers offered four types of molasses-urea based supplement on one day

The supplements consisted of molasses containing 74 g urea/kg (M8U), molasses containing 107 g urea/kg (M12U), M8U containing monensin (M8U-M), and M8U containing meatmeal (M8U-MM). Analysis of variance of the per cent non-eaters was carried out following arcsin transformation of results. The mean values for each treatment are the equivalent means as percentages; the values in parentheses are the mean or s.e.m. of the transformed values

Measurement	Supplement				s.e.m.	Significance
	M8U	M12U	M8U + M	M8U + MM		
Intake of supplement (kg DM/day)						
Week 1	1.12	0.96	1.00	0.73	0.212	n.s.
Week 2	1.58	1.07	1.24	0.96	0.173	n.s.
Week 3	1.78	1.03	1.06	1.49	0.218	n.s.
Mean	1.49	1.02	1.10	1.06	0.197	n.s.
Variability in supplement intake (CV%)	39	37	39	58	12.0	n.s.
Non-eaters of supplement (%)	0	0	0	7	–	–
	(0)	(0)	(0)	(0.27)	(0.132)	n.s.

n.s., Not significant.

There was a relationship between the intake of the lithium-labelled molasses-based supplement in Expts 1 and 2 (X, g/day) and the CV of intake of lithium-labelled supplement (Y, %) in the respective paddock group as follows:

$$Y = 77 \text{ (s.e. 17)} - 0.054 \text{ (s.e. 0.023)}X$$

$$(n = 12, r = 0.54, P < 0.05, \text{r.s.d.} = 13.4)$$

Experiment 3

Rainfall from the seasonal break on the 3 August 1995 until the commencement of the experiment on 19 January 1996 was 700 mm, and rainfall during the experiment consisted of 23 mm in late January, 28 mm in March, 27 mm in April, 13 mm in May, and 37 mm in early June. Mean supplement DM contents were 967 g/kg for the –CSM, and 931 g/kg for the +CSM supplements.

Voluntary intake of the LMM supplements measured by disappearance from the troughs varied widely throughout the 19 weeks of the experiment (Fig. 2). On average the intake of the +CSM supplement was higher ($P < 0.001$) than for the –CSM supplement (79 and 41 g DM/day, respectively), and was higher ($P < 0.05$) for naive than for experienced heifers (68 and 52 g DM/day, respectively) (Table 3). Due to this difference in intake and the differing contents of N and P in the supplements, heifers offered the +CSM supplement consumed about 67% more total N, 30% more urea N, and 40% more phosphorus in the supplement. Supplement intake by individual heifers was not related to their LW. Intake of lithium-labelled supplement was, on average, 83% of the intake of non-labelled supplement during the preceding 2–3 days (70 and 91 g DM/head, respectively). Also, after 17 weeks the per cent non-eaters tended ($P = 0.05$) to be greater for the heifers offered –CSM than for those offered +CSM supplement. On average, the CV of intake among heifers and the per cent non-eaters of the lithium-labelled supplement was 77% and 12%, respectively. Across all treatments and the 3 measurement times there were curvilinear relationships between the per cent non-eaters of supplement in a herd and both the mean intake of the supplement by all the heifers in the group (Fig. 3*a*) and the mean intake by all the heifers in the group that consumed some supplement (Fig. 3*b*). The per cent non-eaters was high at low intakes of supplement but was always ≤10% when the average supplement intake of the group exceeded about 60 g DM/day or 0.2 g DM/kg LW.day.

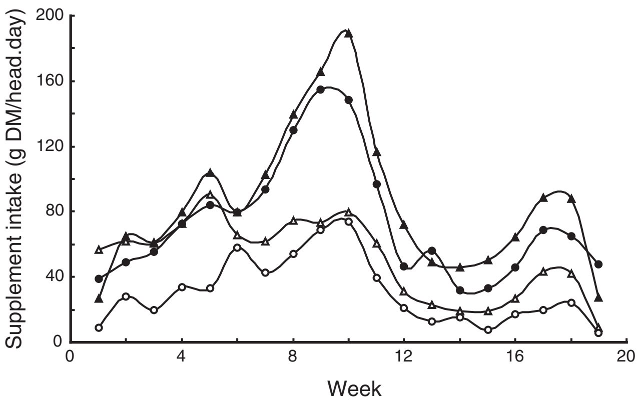

Fig. 2. Expt 3. Voluntary intake of loose mineral mix (LMM) supplement dry matter by 4 treatment groups of heifers during 19 weeks of the late wet and early dry seasons. The treatments were heifers with extensive previous experience of LMM supplements and offered LMM supplement containing nil (○) or 300 g (●) cottonseed meal/kg, or heifers with no previous experience of LMM supplements and offered LMM supplement containing nil (△) or 300 g (▲) cottonseed meal/kg.

Table 3. Liveweight (LW), body condition score (CS), changes in LW and CS, voluntary intake of supplement and of lithium-labelled supplement offered on one day, the coefficient of variation (CV%), and the per cent non-eaters of this lithium-labelled supplement offered on three occasions to heifers

The heifers had no (naive) or extensive (experienced) previous experience of loose mineral mix (LMM) supplement, and during the present experiment were offered LMM containing either no cottonseed meal (–CSM) or containing 300 g cottonseed meal per kg (+CSM) in 24-ha paddocks. Analysis of variance of the per cent non-eaters was carried out following an arcsin transformation of the data. The mean values for each treatment are the equivalent means as percentages; the values in parentheses are the mean (or s.e.m.) of the transformed values

Measurement	Supplement (–CSM)		Supplement (+CSM)		s.e.m.	Significance		
	Naive	Experienced	Naive	Experienced		Supplement	Experience	Supplement × experience
Initial LW (kg)	215	218	215	216	1.15	n.s.	n.s.	n.s.
Initial CS	5.0	5.2	4.9	5.0	0.08	n.s.	n.s.	n.s.
LW change (kg/day)	0.63	0.62	0.64	0.61	0.026	n.s.	n.s.	n.s.
CS change	1.1	1.0	1.1	1.0	0.097	n.s.	n.s.	n.s.
Mean intake of LMM supplement (Week 1–19) (g DM/day)	51	31	85	74	3.7	***	*	n.s.
Intake of lithium-labelled supplement (g DM)								
Week 7	63	36	93	81	17.3	n.s.	n.s.	n.s.
Week 11	76	36	153	124	11.1	**	*	n.s.
Week 17	29	13	58	60	9.71	***	n.s.	n.s.
Non-eaters of supplement (%)								
Week 7	2	28	0	1				
	(0.15)	(0.56)	(0.00)	(0.11)	(0.183)	n.s.	n.s.	n.s.
Week 11	1	54	0	1				
	(0.11)	(0.82)	(0.00)	(0.11)	(0.202)	n.s.	n.s.	n.s.
Week 17	7	47	5	2				
	(0.262)	(0.752)	(0.215)	(0.154)	(0.133)	n.s.	n.s.	n.s.
Variability of supplement intake (CV%)								
Week 7	67	70	60	97	14.4	n.s.	n.s.	n.s.
Week 11	68	73	55	58	11.7	n.s.	n.s.	n.s.
Week 17	72	150	93	66	14.7	n.s.	n.s.	*

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$; n.s., not significant.

Also, there was a relationship between the mean intake of lithium-labelled supplement by all the heifers in the paddock group (X, g DM) and the CV of supplement intake (Y, %) for the 34 measurements where at least 3/10 heifers consumed lithium-labelled supplement as follows:

$$Y = 150 - 95.5\,(1 - e^{-0.0235X})$$

$$(n = 34, R^2 = 0.30, P < 0.01, \text{r.s.d.} = 27.0)$$

On average, the heifers gained 0.63 kg LW/day through the 19 weeks of the experiment but LW gain did not differ among the treatments.

Discussion

In the seasonally dry tropics of northern Australia, cattle often lose liveweight during the dry season (Winks 1984). Such liveweight losses can be alleviated by non-protein nitrogen-based supplements such as the LMM and feed block supplements used in the present studies, whereas protein meal or molasses-urea supplements providing both metabolisable energy and nitrogen are generally necessary to maintain animal growth through the dry season (Winks 1984; Dixon and Doyle 1996). Thus the various supplements used in the present studies each have roles that depend on the required level of animal performance and the seasonal conditions.

Supplement type, supplement intake, and variability in intake

Voluntary intakes of M8U (mean 3.7 and 5.7 g DM/kg LW.day in Expts 1 and 2, respectively) were within the range often observed for this supplement for cattle grazing dry-season native pastures in the tropics of north-eastern Australia (Nicol *et al.* 1984; Lindsay and Laing 1996; Dixon *et al.* 2001). We are not aware of any reports on intake and use of M8U supplement by grazing cattle in other environments. The higher intake of M8U in Expt 2 may have been because these measurements were made later in the dry season when less pasture would have been available and the pasture was likely to be of lower nutritive value. The 26–32% reductions in voluntary intake of the molasses-based supplement due to the inclusion of the monensin or

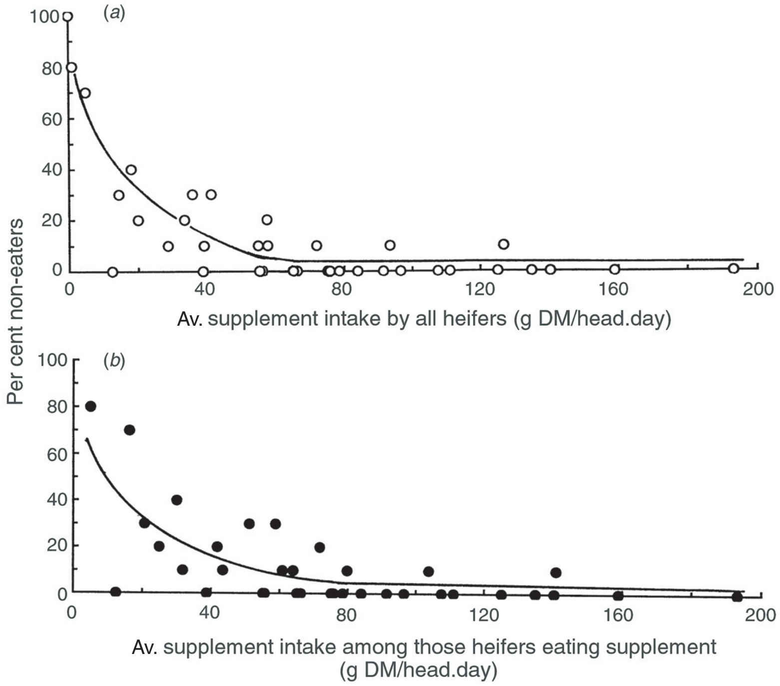

Fig. 3. Expt 3. The relationship between the average voluntary intake of lithium-labelled loose mineral mix (LMM) supplement dry matter (*a*) for all heifers in the group (○, X_1), or (*b*) for all heifers in the group that consumed supplement (●, X_2), and the per cent non-eaters of the supplement (Y) in each of 12 paddock groups of heifers ($n = 10$) measured on 3 occasions during the late wet and early dry seasons. Two types of LMM supplement were offered and the heifers varied in their experience of LMM supplements before the present experiment commenced. The relationship for (*a*) is described by the equation:

$$Y = 92.6 - 88.3(1 - e^{-0.0839X_1})$$

($n = 36$; $R^2 = 0.82$; $P < 0.001$; r.s.d. = 10.3)

The relationship for (*b*) is described by the equation:

$$Y = 82.1 - 79.5(1 - e^{-0.0479X_2})$$

($n = 35$; $R^2 = 0.52$; $P < 0.001$; r.s.d. = 13.4)

meatmeal, or to increasing the urea content to 107 g/kg (i.e. M12U), are in agreement with previous reports of the effects of inclusion of these ingredients into molasses supplements (Beames 1960; Silvestre *et al.* 1977; Knight *et al.* 1984; Nicol *et al.* 1984; Gulbransen and Elliott 1990). The observations that all heifers consumed at least some M8U, M12U, and M8U-M supplement and the CV of 24–39% in intake of the molasses and the CSM supplements in the present studies are in agreement with the ranges observed for similar molasses-based and CSM supplements offered to young cattle grazing small paddocks (Dixon *et al.* 2001). Similar CV and a low per cent non-eaters of grain and protein meal supplements have also been reported for small groups (n = 10–20) of sheep grazing small paddocks and where trough space was not likely to be limiting (Dove 1984; Dove and Freer 1986; Holst *et al.* 1997). In Expt 1 the CSM was offered in 3 separated troughs with about 0.5 m trough edge per heifer (the troughs were surrounded by heifers while the CSM was being consumed); that all heifers consumed at least some lithium-labelled CSM is in accord with observations at feeding that there was sufficient space for all heifers and that usually all heifers were at the supplement trough to consume CSM simultaneously. We are not aware of any studies of the effects of trough space allocation on the variability of intake of concentrate supplements offered infrequently to cattle. However, with sheep, Kendall *et al.* (1980*b*) reported that as trough space allocation was increased from 0.33 to 0.54 m/sheep the CV of intake of a small allocation of concentrate was reduced from 74% to 46%. Since cattle presumably require more trough space per head than sheep because of their larger size, it is likely that the CV of intake of CSM supplement in Expt 1 of the present studies would have been reduced by the provision of greater trough space availability for feeding.

The ingredients added to the M8U molasses supplement to reduce voluntary supplement intake in Expt 2 of the present studies did not, with the possible exception of meatmeal, change either the variability among individuals in supplement intake or the per cent non-eaters. Although the addition of meatmeal did not have a significant effect ($P > 0.05$) and appeared to have no effect in one paddock group, in the second paddock group offered this supplement 6/20 (30%) heifers were non-eaters. This latter percentage was comparable with a previous report where 14/37 (38%) of a herd of heifers also offered molasses-meatmeal supplement *ad libitum* did not consume any supplement (Llewelyn *et al.* 1978). These suggestions that inclusion of meatmeal in supplements can induce a substantial proportion of cattle to be non-eaters of supplement are consistent with anecdotal reports of difficulties on commercial cattle properties with initial consumption of supplements containing meatmeal.

When LMM and block supplements were offered the variation among heifers in supplement intake (CV 55–118%) was much higher, and also in some cases the per cent non-eaters was higher, than for the CSM and molasses supplements. This high variability within groups appears to be characteristic of LMM and block supplements (Kendall *et al.* 1980*a*, 1983; Lobato *et al.* 1980; Dixon *et al.* 2000, 2001). A higher CV for LMM and block supplements than for concentrate supplements may be simply because the variability in intake of supplements by cattle and sheep tends to be constant across a range of voluntary supplement intakes and the voluntary intake of LMM and block supplements is usually relatively low. In addition, the high variability between weeks in intake of each of the supplements offered *ad libitum* in the present studies is in agreement with numerous previous reports (Rocks *et al.* 1982; Weber *et al.* 1992; Tait and Fisher 1996; Dixon *et al.* 2001).

The inverse relationships between voluntary intake of LMM supplement and the per cent non-eater heifers and variability in Expt 3, and the voluntary intake of molasses-based supplements and variability in supplement intake in Expts 1 and 2, suggest a general inverse relationship between the voluntary intake of a supplement and the variability in supplement intake among individual animals in the group. The variety of marker methods used to measure variability in supplement intakes makes comparisons between studies difficult. Nevertheless, a similar inverse relationship between the per cent non-eaters and the voluntary intake of supplement can be calculated from the data of Rocks *et al.* (1982) with sheep fed block supplements, and has been observed in large groups of cattle fed LMM (Dixon *et al.* 2000) and sheep fed blocks (Ducker *et. al.* 1981). The greater variability associated with LMM and block supplements than with concentrate and molasses-based supplements discussed above is also consistent with the hypothesis.

Variability in supplement intake is presumably not related to voluntary intake of the supplement where factors other than appetite for the supplement constrain intake of supplement. For example, voluntary intake of supplement may be constrained by neophobia of the supplement or feeders, or by the need for the animals to learn to obtain supplement from a feeder, or to manipulate a lick feeder (Chapple and Lynch 1986). In addition, there may be intrinsic differences associated with the form of the supplement and the group and/or paddock size. Kendall *et. al*. (1980*a*) reported that the variability in supplement intake was greater when supplement was offered as blocks rather than as loose concentrates, and the variation in supplement intake and in the per cent non-eaters appears to be greater with large groups of cattle (Murray *et al.* 1978; Eggington *et al.* 1990; Sowell *et al.* 1995; Dixon and Smith 2000; Dixon *et al.* 2000) or sheep (Nolan *et al.* 1975) than with small groups in small paddocks (present studies; Dixon *et. al*. 2001). The extent to which these differences are associated with factors such as competition for supplement feeder access, grazing behaviour, stocking rate, and size of the herd is not known.

Consequences of inclusion of CSM into LMM and previous experience of the cattle on intake of supplements

Voluntary intake of supplements offered *ad libitum* is, as for any component of the diet, likely to be a consequence of both innate flavours (Heady 1964) and conditioned flavour responses (Provenza 1995, 1996; Arsenos and Kyriazakis 1999). Both of these factors may have influenced voluntary supplement intake in the present studies. CSM contains components such as protein and metabolisable energy that are likely to develop conditioned flavour preferences (CFP) in cattle grazing pasture of low to moderate quality, and all of the heifers had been exposed to supplements containing CSM before the experiments commenced. The CSM may also have been innately attractive to the cattle. Irrespective of the relative importance of innate and acquired preferences for CSM, it was clear that inclusion of CSM in the LMM in Expt 3 substantially increased voluntary DM intake of LMM supplement and also increased the voluntary intake per day of the urea, total N, and phosphorus contained in the supplement. Voluntary intake of the 2 LMM supplements offered in Expt 3 was apparently not determined simply by a balance of the CFP and conditioned feed aversions (CFA) to achieve the same intake of supplement total N or of urea N. Thus, inclusion into LMM supplements of CSM, or of other feedstuffs attractive to cattle, is likely to be effective in increasing voluntary intake of such supplements when intake of specific nutrient(s) is lower than the expected requirements of the animals for a target level of production.

There was clear evidence that prolonged previous experience of the heifers of Herd A origin with M8U supplements for 5 months during the dry season prior to the experiment increased their intake of the restricted amount of CSM supplement offered in Expt 1. Since the heifers of Herd A origin consumed more lithium-labelled CSM even when intakes were expressed on a g/kg LW basis, it appears that these heifers had a greater motivation to consume, and/or a greater ability to compete for, the restricted amount of CSM supplement. The absence of a difference between the heifers of the 2 herds of origin in intake of M8U, LMM, or block supplements offered *ad libitum* in Expt 1 supports the hypothesis that the difference in intake of a restricted amount of CSM was associated with competition between the heifers for the supplement. Possibly the 30 kg greater LW of the heifers of Herd A origin allowed them to compete more effectively. Associations have sometimes been observed between animal size and social dominance in cattle (Collis 1976; Beilharz and Zeeb 1982), and correlations between liveweight and intake of a concentrate supplement by cattle (Dixon *et al.* 2001) and of blocks by sheep (Lobato and Beilharz 1979) have been reported. There was evidence from Expt 2 as well as from Expt 1 that experience of M8U supplement during the previous dry season by the heifers of Herd A origin increased intake of molasses-based supplements; voluntary intake of the lithium-labelled molasses supplements was 25% higher for the heifers from Herd A than from Herd B. In addition, experience of the M8U supplement for 10 weeks during Expt 1 increased supplement intake in Expt 2. Thus, in these experiments, previous experience of molasses-based supplements could increase the subsequent voluntary intake of the same type of supplement.

In contrast to these results obtained in Expts 1 and 2, in Expt 3 the previous experience by the heifers of a LMM supplement had a significant effect to decrease, not increase, voluntary intake of a similar LMM supplement. This observation is also in contrast with an experiment with similar cattle, pastures, and supplements where previous exposure of weaner cattle to a palatable CSM supplement, or to a high-urea LMM supplement, initially increased voluntary intake of a high-urea LMM supplement during the dry season (Dixon *et al.* 2001). We hypothesise that the results in the various experiments were the consequences of the innate attractiveness of some of the supplements as feedstuffs (Heady 1964) and the development of CFP and CFA to the various supplements when they were fed previously to the heifers (Provenza 1995; Arsenos and Kyriazakis 1999). Supplements of CSM, M8U, or small amounts of urea in LMM ingested during the dry season with low protein pasture would be expected to improve the nutritional status of growing cattle and thus develop CFP to these supplements. However, the ingestion of the same amount of urea in LMM supplement with high-protein wet season pasture would be expected to cause CFA. There is considerable evidence for the development of CFA to dietary urea when the amount of ammonia derived from hydrolysis of the ingested urea exceeds the rate at which the absorbed ammonia can be metabolised to urea (Martz *et al.* 1973; Chalupa *et al.* 1979; Kyriazakis and Oldham 1993). Indeed, it has been demonstrated that sheep consuming low protein diets will acquire CFP to low doses, and CFA to high doses, of urea or casein (Villalba and Provenza 1997; Arsenos and Kyriazakis 1999). It is to be expected that a high-urea LMM supplement could cause either CFP or CFA, depending on the amount of urea consumed and the dietary nitrogen being ingested concurrently from pasture. Thus in Expts 1 and 2 the heifers previously offered M8U could be expected to consume more of this supplement because they had developed CFP for this supplement. However, in Expt 3 the 'experienced' heifers may have had more strongly developed CFA than the 'naive' heifers to urea in the LMM due to the previous consumption of urea-containing LMM. The experienced heifers had, on average, consumed about 26 g urea per day for 6 months during the previous dry season. Thus when the experienced heifers were offered LMM containing 150 or 224 g urea/kg during the late wet and early dry season and when pastures would have been of much higher protein content, an established CFA may have caused them to consume less of the supplement. This mechanism could explain the lower voluntary consumption of LMM supplements by heifers previously exposed to LMM than by those without experience of LMM supplement in Expt 3.

In conclusion, the present studies show that when supplements are provided to grazing cattle the per cent non-eaters and the variability are likely to be much greater when cattle consume low intakes of LMM and block supplements than higher intakes of concentrate and molasses supplements. Although previous experience with supplements can influence intake and variability in intake of such supplements, the present studies suggest that the magnitude of such effects is likely to be less important than the type of supplement provided.

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