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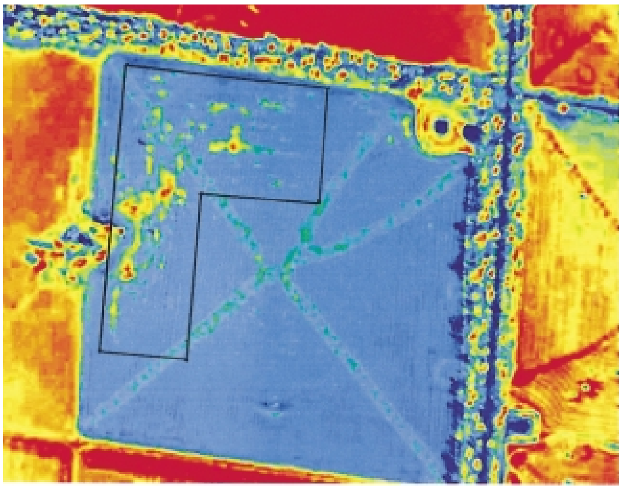

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Effects of experience on voluntary intake of supplements by cattle

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Abstract. Experiments examined the effects of prior experience of young cattle on their voluntary intake of supplements, and variability among animals in intake of supplements. Variability was measured using supplement labelled with lithium salts. Experiment 1 examined the effects of offering a concentrate supplement to calves before and/or after weaning on their subsequent intake of the same supplement and of a loose mineral mix supplement. Experience of the concentrate supplement increased acceptance and reduced variability in intake of the loose mineral mix supplement. However, neither voluntary intake (mean is 105 g DM/head.day) nor variability in intake of loose mineral mix supplement was affected by prior experience. Experiments 2 and 3 examined variability in intake of loose mineral mix supplement by weaners in larger groups or offered molasses–urea supplement, respectively. Experiment 4 examined the effects of provision of supplements and/or exposure to human activity and handling on subsequent intake of loose mineral mix supplement. Supplementing grazing weaners with concentrates had a transient effect by increasing voluntary intake of loose mineral mix supplement, but increased exposure to supplements, and human activity and handling while held in yards after weaning had no effects. Variability among animals in intake of loose mineral mix supplement (CV is 52–103%) tended to be greater than with the concentrate or molasses-based supplements (CV is 23–43%), irrespective of previous experience. There were fewer than 1% non-eaters of concentrate supplement and 0–7% non-eaters of loose mineral mix supplement. In experiment 5, prior experience of loose mineral mix supplements increased intake of such supplements by weaners during weeks 1 and 2 but not from weeks 3 to 9. In experiment 6, intake of loose mineral mix supplement by adult cattle was not affected by their experience as weaners of a similar supplement. In conclusion, although prior experience of supplements by young cattle sometimes increased their initial acceptance and voluntary intake of supplements, longer-term intake of supplements was not affected.

Additional keywords: supplement intake, supplement variability.

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 often 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). Mineral and non-protein nitrogen supplements are often provided to grazing ruminants to alleviate such inadequacies but their effectiveness is often reduced by the difficulties of achieving target intakes of supplement by all animals in the herd (Bowman and Sowell 1997). In extensive grazing systems such supplements are usually provided *ad libitum* as loose mineral mixes (LMM), solidified feed blocks or liquid molasses-based supplements fed through lick dispensers. Factors such as soil fertility, the forage available, season of the year, mineral content of drinking water, palatability of the supplement, location of supplementation points and hardness of blocks may influence intake of such supplements (Pamp *et al.* 1976; McDowell 1992). However, studies where cattle have been offered supplements *ad libitum* as blocks (Murray *et al.* 1978; Eggington *et al.* 1990), molasses–urea fed through a lick dispenser (Nolan *et al.* 1974) or LMM (Dixon *et al.* 1998, 2000) have shown that a substantial proportion of the animals in a herd may not consume any supplement. Furthermore, the variability in supplement intake may be high among the animals that do consume supplement. Similar results have been reported for sheep (Nolan *et al.* 1975; Lobato and Pearce 1980*b*; Wheeler *et al.* 1980; Ducker *et al.* 1981). The proportion of non-eaters of supplement and the variability in supplement intake appears to be inversely related to voluntary intake of the supplement (Dixon and Petherick 1996; Dixon *et al.* 1998, 2000). The

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acceptance and degree of preference by grazing animals for a specific supplement is likely to depend on recognition by the animal of the supplement as a potential foodstuff, prior experience of the animal with the same or similar supplements and the degree of preference of the animal for the supplement relative to available forages (Pamp *et al.* 1976; Muller *et al.* 1977; Chapple and Lynch 1986; Provenza 1996). Experience of young sheep with both supplement feeders and supplements has been shown to increase the subsequent acceptance and intake of the same and similar supplements (Large 1965; Lobato *et al.* 1980*a*; Chapple *et al.* 1987), while prior experience can modify the intake of specific plant species (Nolte *et al.* 1990; Squibb *et al.* 1990; Walker *et al.* 1992).

Experiments were conducted to investigate the extent to which early experience of cattle with supplements and handling by humans influenced their subsequent intake of concentrate and LMM supplements. Measurements were made of voluntary intake of supplements by paddock groups of cattle and, by using lithium as a marker, of intake of supplement by individual animals. In experiment 1, young cattle were exposed to concentrate supplement before and/or after weaning, and the consequences on their subsequent intake of concentrate and LMM supplements while grazing were examined. The same weaners were used in experiments 2 and 3 to measure variability in LMM supplement intake by cattle grazing in larger group sizes and also the variability in intake of a molasses-based supplement. In experiment 4, the effects of exposure to supplements and/or human activity and handling by stockmen for an interval shortly after weaning, of initially providing a concentrate rather than a LMM supplement for grazing weaners, or of frequent handling before weaning, on intake of LMM supplement were examined. In experiments 5 and 6, the consequences of previous exposure of young cattle to LMM supplements on their voluntary intake 2–4 months or 27–32 months later, respectively, were examined.

Materials and methods

General

Young *Bos indicus* × *Bos taurus* cattle from the Swan's Lagoon Research Station herd were used in the experiments. This herd had been managed as a genetically closed herd for 2 decades, with management and selection such that the cattle were generally of docile temperament and accustomed to frequent mustering and handling. The pastures comprised tropical grasses native or naturalised to the open eucalyptus woodlands of the northern speargrass region of coastal north-eastern Australia. Major grass species were black spear grass (*Heteropogon contortus*) with other tropical tall grasses and medium grasses, including *Chrysopogon fallax* and *Bothriochloa pertusa*.

Except where otherwise stated, fresh supplements were offered and supplement residues removed twice each week. Supplement was offered to each paddock group in a single 2.4 m trough situated about 20 m from the water trough that comprised the only water point in the paddock. The troughs used to feed the LMM supplements were open-ended to allow drainage of rainwater. The amount of LMM supplement offered was adjusted frequently with the intention to achieve *ad libitum* intakes with refusals of 10–30% of that offered. Dry matter (DM) content of supplements offered and refused was determined by oven drying at 70°C. Intake of supplement by individual animals was measured on occasions by providing lithium-labelled supplement [about 2 mg lithium/kg liveweight (LW)] on one day and determination of lithium concentration in plasma sampled the following day (Suharyono *et al.* 1991; Suharyono 1992). Lithium-labelled LMM or molasses–urea supplement was offered in the supplement trough at about 0700 hours, before cattle usually moved to the water point for the day, and was removed at about 1700 hours, after the cattle had left the water point. Cattle were mustered commencing at 0630–0730 hours on the day after the lithium-labelled supplement was offered. Between 0900 and 1100 hours and before access to water the cattle were weighed and blood sampled by jugular puncture using vacutainers containing potassium EDTA as an anticoagulant. Plasma was separated immediately by centrifugation and stored frozen.

Experiment 1

This experiment consisted of 4 phases as summarised in Table 1. During phase 1, 6 herds of cows (n = 20–25) with calves grazed 6, 100-ha paddocks arranged in 3 blocks. One of the herds in each block was, for 7 weeks commencing during the wet season in mid January, offered the equivalent of 2.77 kg supplement DM per cow/calf unit per day of a concentrate supplement. The concentrate contained (g/kg) 660 cottonseed meal, 250 cracked sorghum grain, 70 Megalac rumen inert protected fat (Volac Ltd, Hertfordshire, UK), 30 mineral premix [containing (g/kg) 20 zinc, 20 manganese, 15 ferrous iron, 5 copper, 0.5 cobalt, 0.5 iodine, 0.1 selenium; (iu/g) 5000 vitamin A, 1000 vitamin D, 3 vitamin E], 8.5 calcium phosphates and 8.5 limestone. The supplement was offered to each herd of cows and calves in 3, 2.4 m troughs. The calves ranged from newborn up to 11 weeks of age when supplementation commenced.

In mid May, when 6 months of age (s.d. = 0.5), the calves (n = 121) were weighed, weaned and allocated by stratified randomisation based on sex and LW to form 2 similar groups within each of the 6 herds. Thus, there were 12 groups each of 9–11 weaners; 6 of these groups had been offered the concentrate supplement before weaning while the remaining 6 groups had no prior experience of supplements. During phase 2, for 2 weeks following weaning, the 12 groups of weaners were held in partially roofed pens (7 by 10 m) with the 3 replicates of each treatment held in adjacent pens to minimise possible effects of animals learning by observation of animals in adjacent pens. Low-quality hay was offered *ad libitum* and 3 of the groups from each of the phase 1 treatments were also offered daily 0.46 kg DM/head.day of the concentrate supplement. Thus, during phases 1 and 2, 4 treatments were imposed on 12 groups of weaners in a 2 × 2 factorial arrangement, the factors consisting of the presence or absence of concentrate supplements at 2 times (i.e. before and after weaning). At the end of phase 2, the weaners were weighed, earmarked, vaccinated (botulism, clostridial diseases and in the case of heifers, leptospirosis; CSL Ltd, Vic.; Smith Kline Animal Health Products, NSW), branded and where necessary dehorned. Bulls were surgically castrated. The weaners then grazed as a single mob for 3 days before phase 3 commenced.

During the 3 weeks of phase 3, the 12 groups of weaners grazed 12, 15-ha paddocks with an estimated >3 t of pasture DM on offer. The groups of weaners from each of the 3 blocks in phases 1 and 2 were allocated randomly within a block of 4 paddocks. Thus, effects of blocks could not be related to any specific phase. Groups of weaners were offered the equivalent to 0.32 kg DM/head.day of the concentrate supplement described above in 2 troughs (0.4 by 0.7 m and 0.6 by 0.8 m, respectively, and 10 m apart). During the first week, the weaners were mustered to the water point if not already present when the supplement was offered. At 0930 hours on the last day of this phase, the weaners were offered a meal (1.14 kg DM/head) of supplement labelled with

Table 1. Brief description of the treatments and activities during the 4 phases of experiment 1

LMM, loose mineral mix

Phase	Duration	Cattle and treatments.
1	Mid Jan.–early March (7 weeks)	Six herds of cows and calves. For 7 weeks 3 of these herds were offered concentrate supplements.
2	Mid–late May (2 weeks)	All calves in the 6 herds were weaned and held in pens. The calves from each herd were allocated into 2 groups so that there were 12 groups of weaners. Six of the 12 groups were offered concentrate supplements.
3	June (3 weeks)	The 12 groups of weaners grazed 15 ha paddocks and all groups were offered concentrate supplement. Individual intakes of lithium-labelled concentrate supplement were measured on 1 occasion.
4	Late June–mid Oct. (16 weeks)	The 12 groups of weaners continued to graze the same paddocks and all groups were offered LMM supplement. Individual intakes of lithium-labelled LMM supplement were measured on 2 occasions.

lithium chloride and the weaners were mustered to the water point if not already present.

Phase 4 commenced immediately after phase 3. For 16 weeks, the groups of weaners continued to graze the same paddocks and were offered a LMM supplement *ad libitum*. This supplement was introduced gradually. Specifically, during week 1 the LMM consisted of (g/kg) 500 cottonseed meal and 500 salt, and during week 2, 500 cottonseed meal, 340 salt, 150 calcium phosphates and 10 sulfur. Urea (50 g/kg) was included during week 3. The LMM offered from week 4 contained (g/kg) 380 salt, 300 urea, 150 cottonseed meal, 150 calcium phosphates and 10 sulfur. Supplement was not offered during week 12 due to a supply problem and intake could not be measured satisfactorily during week 16 due to rain washing some of the supplement from the troughs. LMM supplement labelled with lithium chloride or lithium sulfate was offered during weeks 5 and 9, respectively.

Experiment 2

This experiment was conducted during the late dry season in October and November. Measurements were made of distribution in intake of LMM supplement among weaners as they grazed in 2 herds (n = 44 and 48) in 2 of the 15-ha paddocks used for experiment 1. Each of the herds consisted of the weaners from one of the blocks of experiment 1, plus 7 additional steers with no prior experience of LMM supplements. These latter steers had been weaned in May, offered hay and molasses-based supplements for 2 weeks while held in yards, and had then grazed irrigated pasture for 5 months. Each herd was offered *ad libitum*, in a single 2.4 m trough, the LMM supplement provided during phase 4 of experiment 1. After 2 weeks, supplement labelled with lithium sulfate was offered to measure individual supplement intakes.

Experiment 3

This experiment was conducted at the same time as experiment 2 and measured the variability in intake of a molasses-based supplement. Four groups (n = 9 or 10) of weaners comprising 1 block of paddocks during experiment 1 were offered M8U (molasses containing 7.4% urea) supplement *ad libitum*. The M8U was offered to each paddock group in a single 0.6 by 0.8 m trough. After 2 weeks, M8U labelled with lithium chloride was offered.

Experiment 4

Heifer calves with low (n = 100) or higher (n = 20) previous exposure to stockmen and human activity were used for the experiment. The heifers with low previous exposure were from 3 herds that had not been mustered or handled since the cows calved. The heifers with higher previous exposure were from a herd that had been mustered and handled through yards 6 times since calving. These calves were weaned in May when LWs were (mean ± s.d.) 154 ± 11 and 154 ± 10 kg, respectively. The heifers were allocated by stratified randomisation based on LW within each herd to 12 groups, 10 head each. The heifers were held in yards for 2–3 weeks (the range reflecting differing muster dates of the various herds) following weaning and 6 treatments were imposed. Four treatments applied to the heifers with low previous exposure consisted of a 2 × 2 factorial arrangement, the factors being (i) provision of hay alone or hay plus supplements, and (ii) exposure to low or high levels of handling by stockmen and human activities. Thus, weaners in treatments T1 and T2 were offered hay alone and experienced low and high levels of handling in the yards, respectively, while those in treatments T3 and T4 were offered hay plus supplements and experienced low and high levels of handling, respectively. Treatment T5 weaners, also derived from the low previous experience group, were offered hay alone with a low level of handling while held in the yards, but then for 6 weeks while at pasture were offered cottonseed meal supplement. Treatment T6 weaners were the heifers from the herd with higher level of handling before weaning. These weaners were offered hay alone with low handling and exposure to human activity while held in the yards.

For 2–3 weeks following weaning, the heifers in treatments T1, T3, T5 and T6 were held in yards 3 km away from any major road and were exposed to a stockman for only about 30 min daily for feeding and monitoring. On 3 occasions, each of about 2 h, these heifers were trained to respond to horsemen by tailing (Fordyce 1987). Weaners in treatments T2 and T4 had higher level of exposure to human activity and handling in the yards by stockmen. The yard where they were held was within 30 m of a frequently used road and on 3 days other cattle were handled elsewhere in the yards. In addition, the weaners were handled on 9 occasions, for 15 min each time. On each occasion, a stockman stood quietly in the yard with the weaners until they had settled down, and then walked quietly through the mob. Also experienced stockman moved these weaners calmly and quietly between yards and through a crush on 3 occasions. These weaners were tailed as described above on 4 occasions. All weaners were fed lucerne hay *ad libitum* while in the yards, the hay being offered on the ground for treatments T1, T2, T5 and T6 and in mesh hay feeders for treatments T3 and T4. These 2 latter treatments were also offered grain-based (g/kg: 760 sorghum grain, 190 cottonseed meal and 50 salt or 800 sorghum grain and 200 cottonseed meal) and molasses-based (907 molasses, 3 urea and 90 cottonseed meal) supplements *ad libitum*. At the end of this phase in the yards, the weaners were vaccinated, branded and dehorned as described for experiment 1.

Following the interval when the weaners were held in yards, groups of 10 weaners (i.e. 2 replicates per treatment) were grazed in 12, 15-ha paddocks for 12 weeks. These were the paddocks previously used for experiment 1 and initially had an estimated >2.5 t of pasture DM on offer. Weaners in all treatments except T5 were offered a LMM supplement *ad libitum*. Treatment T5 weaners were offered the equivalent of 0.32 kg cottonseed meal DM/head.day during weeks 1–6, and LMM supplement *ad libitum* during weeks 7–12. The LMM offered during the first week consisted of (g/kg) 440 salt, 300 cottonseed meal, 150 calcium phosphates, 100 urea and 10 sulfur, while the mixture offered thereafter consisted of (g/kg) 370 salt, 300 urea, 150 cottonseed meal, 150 calcium phosphates and 30 sulfur. LMM or cottonseed meal supplement labelled with lithium sulfate was offered during weeks 6 and 12. These treatments are summarised in Table 2.

Experiment 5

Sixty heifers (LW = 168 ± 14 kg, mean ± s.d.) selected at random from those used in experiment 4 were allocated by stratified randomisation based on LW into 6 paddock groups, each of 10 head. Thus, these heifers had extensive previous experience of LMM supplements. These heifers had continued to graze the experimental paddocks for 7 weeks following experiment 4 and before experiment 5 commenced. In addition 28 heifers weaned in August (LW = 160 ± 12 kg, mean ± s.d.) were randomly allocated into 4 groups, each of 7 head. These weaners had been offered molasses-based supplements and hay for 2 weeks in yards following weaning, but had no other prior experience of supplements. The 6 groups of heifers with previous experience and 4 groups of heifers without experience of LMM supplements were each randomly allocated into 2 LMM-supplement-mix treatments. The 10 groups of heifers were then allocated randomly to 15-ha paddocks consisting of 6 paddocks used during experiment 4, and another 4 similar paddocks. One LMM mixture consisted of (g/kg) 640 salt, 300 urea and 60 ammonium sulfate, while in the second mixture 320 g/kg of the salt was replaced by cottonseed meal. The supplements were offered for 9 weeks during the late dry season (late September to early December) commencing 2 weeks after the weaners were allocated to the paddocks. Voluntary intake of supplement was measured. Supplement labelled with lithium sulfate was offered during weeks 4 and 10, but because of storm rain on both these occasions no measurements of variability in supplement intake were made. The effects of the type of LMM supplement and the prior experience of LMM supplement on voluntary intake of such supplement were examined as a 2 × 2 factorial arrangement.

Experiment 6

Forty steers weaned in May (LW = 188 ± 9 kg, mean ± s.d.) were allocated by stratified randomisation based on LW to 8 paddock groups, and each of these groups grazed with 19 pregnant heifers and 6 pregnant cows in 100 ha paddocks. From July to November, during the dry season, 4 of the paddock groups were offered *ad libitum* in 2, 2.4 m troughs a LMM supplement (g/kg: 318 cottonseed meal, 273 urea, 182 salt, 136 calcium phosphates and 91 ammonium sulfate) while the other 4 groups were not supplemented. Then for 27 months from November onwards, the steers grazed as a single herd and did not have access to any supplements. At the end of this interval the steers were reformed into their previous 8 paddock groups, which were allocated randomly to 8, 40-ha paddocks. For 20 weeks from the mid wet season until the mid-dry season (March–July), all the paddock groups were offered *ad libitum* in a single 0.6-m diameter trough a LMM supplement (g/kg: 448 salt, 313 calcium phosphates, 224 urea and 15 sulfur) in open-sided sheds (3 by 3 m). Supplement intake was measured twice weekly.

Laboratory analyses, *calculations and statistical analyses*

Plasma was protein precipitated by addition of 1 mL plasma to 5 mL 2% trichloroacetic acid. Lithium concentration in the supernatant thus obtained 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. The net concentrations of lithium in plasma, the animal LW and the total intake of lithium-labelled supplement by each paddock group were used to calculate the intakes by all individual cattle in the paddock of the consumed lithium-labelled supplement (Suharyono *et al.* 1991; Suharyono 1992). Non-eater animals were defined as those that consumed less than 1 g of lithium-labelled supplement during the interval during which it was provided; this generally coincided with a lithium concentration in plasma <1.5 times the mean background concentration.

The data were examined by linear regression and analysis of variance where the paddock groups were considered as the experimental unit. In experiments 1 and 5, the 4 treatments were considered as a 2 × 2 factorial arrangement with 3 and 2 replicates, respectively, associated with the blocks of paddocks. In experiment 2 the intakes of lithium-labelled supplement and animal LW of the 5 subgroups of animals with various previous experience were compared within paddocks. In experiment 4, the 2 replicates of the 6 treatments were compared separately for weeks 1–6 and weeks 7–12 of grazing. In addition, in experiments 1, 4, 5 and 6, the effects of treatment on the voluntary intake of supplements were examined in a repeated measures model that included the effects of time (i.e. week of supplementation) and the interaction between time and treatment (Payne and Arnold 1998). Skewness of the distribution of intake of lithium-labelled supplement among animals was examined as described by Snedecor and Cochran (1967).

Table 2. Brief description of the treatments and activities during experiment 4

LMM, loose mineral mix

Treatment	Pre-weaning phase	Held in yards, 2–3 weeks immediately after weaning	Grazing, weeks 1–6 after the phase in yards	Grazing, weeks 7–12 after the phase in yards
T1	Herds of cows and calves not mustered or handled by stockmen	Fed hay alone; low exposure to stockmen	Offered LMM supplement	Offered LMM supplement
T2	Herds of cows and calves not mustered or handled by stockmen	Fed hay alone; high exposure to stockmen	Offered LMM supplement	Offered LMM supplement
T3	Herds of cows and calves not mustered or handled by stockmen	Fed hay + supplements; low exposure to stockmen	Offered LMM supplement	Offered LMM supplement
T4	Herds of cows and calves not mustered or handled by stockmen	Fed hay + supplements; high exposure to stockmen	Offered LMM supplement	Offered LMM supplement
T5	Herds of cows and calves not mustered or handled by stockmen	Fed hay alone; low exposure to stockmen	Offered cottonseed meal supplement	Offered LMM supplement
T6	Herds of cows and calves mustered and handled by stockmen on 6 occasions	Fed hay alone; low exposure to stockmen	Offered LMM supplement	Offered LMM supplement

Table 3. Experiment 1. Effect of offering concentrated supplements to calves for 7 weeks before weaning (phase 1) and/or for 2 weeks following weaning in the yards (phase 2) on their liveweight and subsequent variation in intake while grazing of concentrate (phase 3) or loose mineral mix (phase 4) supplements

	No supplements during phase 1		Plus supplements during phase 1		s.e.m.	Significance		
	No supp. during phase 2	Plus supp. during phase 2	No supp. during phase 2	Plus supp. during phase 2		Phase 1	Phase 2	Interaction of phases 1 and 2
			Liveweight (kg)					
Weaning	180	178	189	191	2.5	**	—	—
End of phase 2	182	181	189	193	3.3	*	n.s.	n.s.
End of phase 3	175	175	183	187	2.5	*	n.s.	n.s.
End of phase 4	175	178	186	185	2.3	*	n.s.	n.s.
			Intake of loose mineral mix supplement (g DM/day)					
Phase 4	99	115	97	110	8.3	n.s.	n.s.	n.s.
			CV (%) of supplement intake					
End of phase 3	42.5	28.9	32.0	23.3	3.19	n.s.	*	n.s.
Phase 4, week 5	63	55	84	62	5.50	n.s.	n.s.	n.s.
Phase 4, week 9	54	52	103	61	14.1	n.s.	n.s.	n.s.

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

Results

Experiment 1

The weaners were in good health throughout the experiment although 3 deaths occurred due to feral dog attacks and 1 animal was removed from the experiment because it would not remain in its designated paddock. The concentrate supplement contained (g/kg) 923 DM, 920 organic matter and 48 nitrogen. The hay fed during phase 2 contained 919 DM, 943 organic matter, 3 nitrogen and had an *in vitro* organic matter digestibility of 538 g/kg. The LMM supplement contained 948 g DM/kg.

Weaners that had been offered concentrate supplements with their dams during phase 1 readily accepted the same supplement when held in pens during phase 2 following weaning. These weaners consumed on average 85, 88 and 97% of the offered supplement on the first, second and third day, respectively, from when the supplement was provided. In contrast, weaners not previously offered the concentrate consumed on average 19, 33 and 98% of the offered supplement on the first, second and third day, respectively. From day 4, all of the groups of weaners consumed 95–100% of the supplement offered.

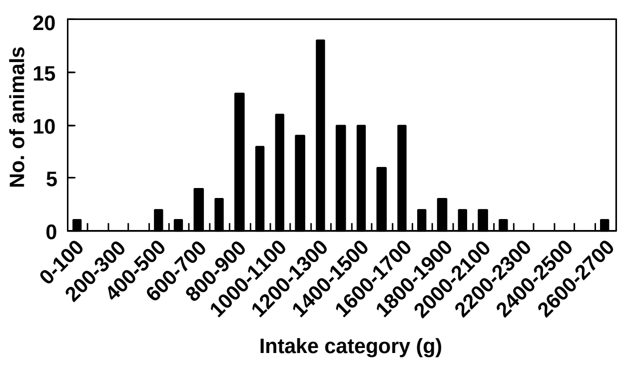

Figure 1. Frequency distribution of intake of lithium-labelled concentrate supplement by weaners during phase 3 of experiment 1.

At the commencement of phase 3 when the weaners were initially offered a 3-day allocation of concentrate supplement in the paddock, all groups that had been offered supplement in pens consumed all of the supplement within 24 h. Weaners that had been offered supplements during phase 1 but not during phase 2 consumed on average 94% of that offered. The weaners not offered supplement in either phase 1 or 2 consumed on average only 47% of that offered within 24 h, but consumed all of the supplement during the 3-day supplementation interval. There were no refusals of supplement by any paddock group during phase 3.

The lithium-labelled concentrated supplement offered at the end of phase 3 was completely consumed by all paddock groups within 2 h. Only 1 weaner of the 117 did not consume any supplement. The coefficient of variation (CV) among animals in supplement intake ranged from 23 to 43% and was, on average, reduced from 37 to 26% (P<0.05) by the provision of supplement in pens during phase 2 (Table 3). Provision of supplements during phase 1 also tended ($P = 0.14$) to reduce this variation and the effects of provision of supplements during phase 1 and 2 appeared additive (Table 3). The frequency distribution of individual intakes of concentrate supplement (Fig. 1) was not significantly (P>0.05) skewed. Individual intakes of supplement were related to animal LW as follows (± s.e.):

$$Y = 239\ (\pm 277) + 5.5\ (\pm 1.53)X$$
$$(n = 117;\ r = 0.32;\ P<0.001;\ \text{r.s.d.} = 375),$$

where Y was the intake of lithium-labelled supplement (g DM) and X was the LW (kg).

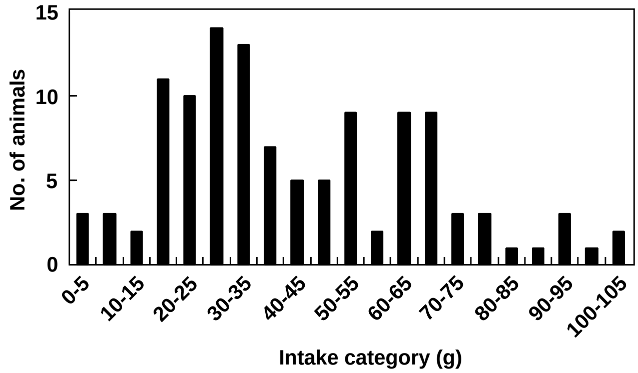

Figure 2. Frequency distribution of the mean intake of lithium-labelled loose mineral mix supplement by weaners measured on 2 occasions during phase 4 of experiment 1.

During phase 4, all paddock groups of weaners consumed at least 66 g LMM supplement DM/head.day during the first week it was offered. Voluntary intake of this supplement (mean is 105 g DM/head.day) was not affected (P>0.05) by provision of supplements during phases 1 or 2 (Table 3). Intake of groups during individual weeks ranged from 74 to 146 g/day and differed (P<0.001) between weeks. Also average voluntary intake increased by 2.5 g/week (r = 0.30, P<0.001) during the supplementation interval. Voluntary intakes of lithium-labelled LMM supplement offered after 5 or 9 weeks were on average 42 and 43%, respectively, of the intake of non-labelled supplement during the preceding 3–4 days. Variation among individual animals in intake of lithium-labelled LMM supplement was not affected (P>0.05) by provision of concentrate supplements during phases 1 and 2 (Table 3). The CV of supplement intake averaged 67% (range is 52–103%), while 7 and 4% of weaners did not consume any supplement at weeks 5 and 9, respectively. The distribution of intakes was significantly (P<0.05) skewed in 3 of the 8 distributions of the 4 treatments at the 2 measurement times, while the frequency distribution for all animals at both times (Fig. 2) did not appear to be skewed. There were no significant correlations (P>0.05) between the intakes of lithium-labelled supplements by individual weaners at weeks 5 and 9 (r = 0.15), nor between these intakes of lithium-labelled LMM supplement and the intake of lithium-labelled concentrate supplement during phase 3 (r = 0.12 and 0.03, respectively).

Calves supplemented with their dams during phase 1 were 11 kg heavier (P<0.01) at weaning and this LW difference was maintained until the end of phase 4 (Table 2). On average, the weaners lost 5 kg from the end of phase 2 in the yards until the end of phase 4, and LW changes during phases 3 and 4 were not affected (P>0.05) by the treatments imposed during phases 1 and 2. Liveweight change during phase 3 was correlated (P<0.05) with the individual intakes of lithium-labelled supplement, but the relationship described only 4% of the variation in LW change. Liveweight change of individual animals during phase 4 was not related (P>0.05) to the individual intakes of lithium-labelled supplement.

Experiment 2

Intake of LMM supplement by the 2 paddock groups averaged 83 and 94 g DM/head.day, while intake of lithium-labelled supplement was 89 and 96% of intake during the preceding 3 days, respectively. The mean LW of the weaners previously supplemented during phase 1 was 191 kg, which was greater (P<0.05) than that of the weaners not supplemented during that phase (174 kg) and that of the steers that had not been used in experiment 1 (178 kg). Only one of the 92 weaners in the 2 paddock groups did not consume any of the lithium-labelled supplement. Among the 5 subgroups within each paddock with differing experience of supplements there were no differences (P>0.05) in intake of lithium-labelled supplement (mean 99, range 85–109 g DM) or in the CV within groups in intake of lithium-labelled supplement (mean is 62, range is 37–79%). The absence of significant differences among subgroups was consistent with the absence of differences among the 4 subgroups during phase 4 of experiment 1 (Table 3); in addition, social facilitation during experiment 2 may have eliminated any differences between the inexperienced subgroup and the remaining animals.

Experiment 3

Mean intake of M8U supplement by the 4 paddock groups offered this supplement averaged 1.22 kg as-fed/day and mean LW of the weaners was 172 kg. Mean intake of lithium-labelled supplement was 0.85 kg as-fed (range is 0.71–1.01 kg). All of the animals consumed some lithium-labelled supplement while the CV within paddock groups averaged 31% (range is 24–41%).

Experiment 4

The heifers were in good health throughout the experiment except for one that died apparently as a consequence of branding and dehorning. Mean DM content of the LMM and cottonseed meal supplements were 951 and 900 g/kg, respectively. Although no measurements were made, observation of the weaners indicated that the additional exposure of the T2 and T4 weaners to handling by stockmen and human activity changed the behaviour of these weaners; by the end of the interval in the yards these weaners were more docile, showed less fear of stockmen, and were more easily handled.

When the weaners were moved to the paddocks all groups of animals offered LMM consumed some of this supplement during the first week it was offered (Fig. 3). Voluntary intake of LMM supplement was not affected (P>0.05) by prior experience of the weaners with concentrate supplements

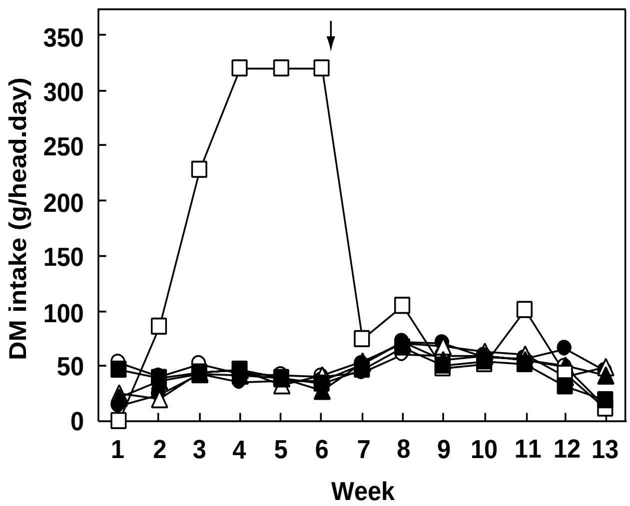

Figure 3. Experiment 4. Voluntary intake (g DM/head.day) of supplements by weaners with various prior experience of concentrate supplements and human activity [treatments T1 (○), T2 (●), T3 (△), T4 (▲) or T6 (■)], or offered cottonseed meal supplement from weeks 1–6 and then loose mineral mix supplement from week 7–12 [treatment T5 (□)]. The arrow indicates the change in supplement for treatment T5. Further details of the treatments are given in the text.

while held in the yards, or by the additional handling by stockmen or exposure to human activity either before weaning (T6) or while in the yards after weaning (T2 and T4). For treatments T1–T4 and T6, the intake of LMM supplement averaged 38 g/head.day during the first 6 weeks in the paddock. There was no rain during this interval. However, the T5 weaners did not consume any cottonseed meal supplement during the first week in the paddock and they did not consume their entire allocation of cottonseed meal until week 4 (Fig. 3). When cottonseed meal supplement was replaced by LMM supplement in weaners given T5, voluntary intake of LMM supplement was 68–80% greater ($P<0.05$) during weeks 7, 8 and 11 than the intake by the T1 weaners that had been offered LMM supplement during the first 6 weeks in the paddock but had otherwise been managed similarly. However, intake of LMM supplement by the T5 weaners did not differ ($P>0.05$) from that of the T1 weaners during weeks 9, 10, 12 or 13 of supplementation. Rain occurred during weeks 11 (27 mm), 12 (56 mm) and 13 (25 mm).

CV of intake of lithium-labelled supplement within groups of weaners after 6 weeks of supplementation in the paddock was 24% for the T5 weaners offered cottonseed meal during weeks 1–6, 54% for the T1 weaners offered LMM but otherwise similar to the T5 weaners, and 54–89% for the other treatment groups offered LMM supplement. The variability in intake of lithium-labelled supplement among the T5 weaners at week 12 when they were offered LMM supplement (CV is 73%) was similar to the CV of intake by weaners from the other treatments measured at the same time (mean CV is 73%). Intake of the lithium-labelled LMM supplement was on average 100 and 80% of the intake of the non-lithium-labelled LMM supplement during the preceding 2 or 4 days for the measurements made during weeks 6 and 12, respectively. The T5 weaners consumed the entire lithium-labelled cottonseed meal supplement. There were no non-eaters of the cottonseed meal supplement, and 6 and 3% non-eaters of the LMM supplement during weeks 6 and 12, respectively.

Experiment 5

The weaners lost on average 0.37 kg LW/day during the experiment and there were no differences between treatments. All the paddock groups of weaners consumed some LMM supplement from the first week the supplement was offered; intakes for the individual paddock groups ranged from 9 to 55 g supplement DM/head.day. Mean intake of supplement during the supplementation interval ranged from 43 to 52 g DM/head.day for the various treatments but did not differ ($P>0.05$) among treatments. Voluntary intake of supplement increased linearly ($r = 0.71$, $P<0.05$) during the 9-week supplementation interval by 3.7 (± 1.24) g supplement DM/week. There was a significant ($P<0.05$) interaction between the previous experience of the weaners with supplements and the week of supplementation (Fig. 4), so that during weeks 1 and 2 the weaners with low experience consumed less ($P<0.05$) than those with higher level of experience. The inclusion of cottonseed meal in the LMM supplement did not affect ($P>0.05$) supplement intake. Rain occurred during weeks 3 (34 mm), 4 (34 mm) and 8 (52 mm).

Experiment 6

During the first dry season when the steers as weaners grazed with adult cattle, the average intake of LMM supplement by all of the animals in the paddocks was 184 g DM/head.day. Measurements using lithium-labelled supplement indicated that all the steers in supplemented paddocks consumed at least some supplement and that LMM intake of the weaner steers was 52% of that of the adult cattle. At 3.0–3.5 years of age the steers were on average 451 kg LW and in ‘forward store’ body condition in the mid wet season (late February) at the commencement of the second interval of supplementation. The steers gained 136 kg (s.d. = 36) LW through the 5 months when the LMM supplement was provided. Voluntary intake of the LMM supplements (Fig. 5) was not affected ($P>0.05$) by the previous experience (when they were weaners) of the steers with LMM supplement. Intakes increased gradually to an average of 70 g/head.day at week 8, and then declined sharply from week 8 to 11. This decrease, and the fluctuations during subsequent weeks, were associated with rain events; there was 24, 8 and 45 mm rain during weeks 7,

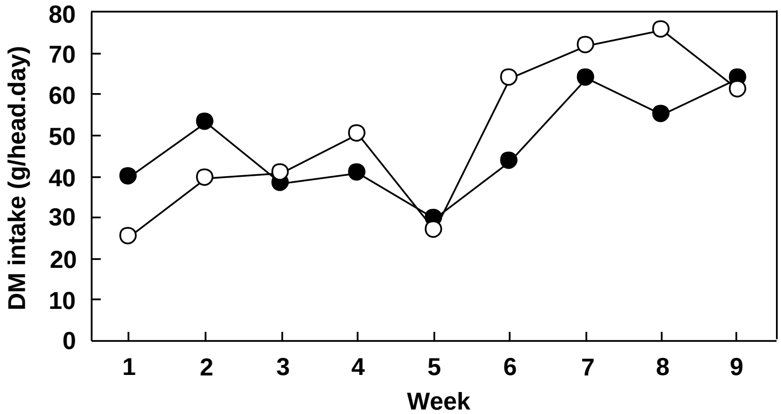

Figure 4. Experiment 5. Voluntary intake (g DM/head.day) of a loose mineral mix supplement by weaners not previously experienced (○) or previously offered loose mineral mix supplement for 12 weeks (●).

9 and 15, respectively. Voluntary intake of supplement declined abruptly several days after rain and increased again slowly over several weeks.

Discussion

Acceptance of supplements and variability within mobs in supplement intake

The more rapid acceptance of concentrate or LMM supplement by weaners with prior experience of the same supplement in experiments 1 and 5 is in agreement with the results of the past studies with sheep offered both concentrate and block supplements (Large 1965; Lobato *et al.* 1980*b*; Chapple and Lynch 1986). Ruminants often exhibit neophobia towards both novel feedstuffs and feeders, and animals typically increase their intake of the feed gradually as this neophobia is overcome (Chapple *et al.* 1987). In addition, it was shown in experiment 1 that prior experience could reduce the variability among animals in intake of a concentrate supplement. This is in agreement with previous reports (Kahn 1994; Bowman and Sowell 1997) that variability in intake of concentrate supplement by sheep declined with increasing experience to the supplement. In experiment 1 of the present study, the experience of the animals in the pens was apparently more important than that before weaning to reduce variability in supplement intake in the paddock, although the effects appeared additive. This was unexpected since, at least in sheep, the mother has a major role in social facilitation, including in the acceptance of supplements (Lobato *et al.* 1980*a*; Green *et al.* 1984; Chapple and Lynch 1986; Thorhallsdottir *et al.* 1987). However, in the present study the experience in pens during phase 2 was immediately before the paddock phase, whereas

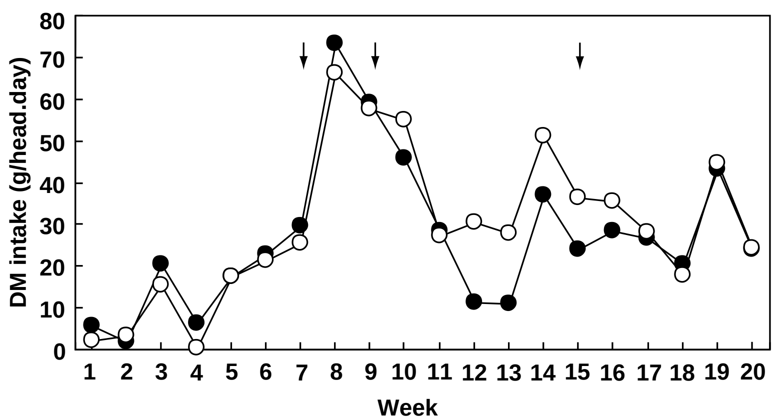

Figure 5. Experiment 6. Voluntary intake (g DM/head.day) of a loose mineral mix supplement by 3-year-old steers which either had not been supplemented (○) or had been previously supplemented (●) for 5 months during their first dry season as weaners with a loose mineral mix supplement. The arrows indicate weeks when rain occurred.

the experience pre-weaning during phase 1 was more than 3 months previously. Also it is possible that the effect arose because more of the animals consumed supplement when confined in pens than pre-weaning when grazing (Lobato and Pearce 1980*a*). The observation in experiment 4 that familiarity of the cattle with humans did not affect intake of the LMM supplement contrasts with the results of Lobato and Pearce (1980*b*) with sheep, but may have been associated with the generally docile temperament of the cattle used in the present studies.

The importance of these observations for management of weaner cattle will vary with circumstances. In many management systems a delay of a few days to achieve high intakes of concentrate supplement by weaners would not be important. However, in some management systems such as extensive cattle properties, weaners grazing large paddocks (e.g. of several thousand hectares) often do not consume any, or sufficient, concentrate supplement. The present study, as well as anecdotal reports, indicate that provision of concentrate supplements to the calves before weaning or while they are held in yards shortly after weaning is likely to increase their subsequent acceptance of supplements.

The generally rapid acceptance of supplements and the low proportion of non-eaters of supplement observed in the present studies may have been associated with several factors. First, except for experiment 6, cattle were offered low quality hay or grazed senesced dry-season pastures. Voluntary intake of LMM supplements tends to be inversely related to forage intake (Riggs *et al.* 1953; Weber *et al.* 1992), while observations and experience both at the research stations and commercial cattle properties indicate that voluntary intake of LMM supplements is usually much higher during the dry season than during the wet season. Second, the cattle used in the experiments had been familiar with water troughs from birth and were from a herd selected for docile temperament; these factors may have alleviated neophobic responses to supplements and supplement feeders. Third, the animals were managed in small groups and in small paddocks, and in experiments 2, 5 and 6 even those weaners with relatively low experience of supplements had been previously offered molasses-based supplements while held in yards shortly after weaning. Fourth, in experiment 2 acceptance of supplements by inexperienced animals may have been increased by social facilitation by the more experienced animals in the same paddock.

The proportion of non-eaters (0–7%) of supplement was lower than the range often observed previously with cattle (Nolan *et al.* 1974; Dixon and Smith 2000; Dixon *et al.* 2000) and sheep (Nolan *et al.* 1975; Lobato *et al.* 1980*b*; Ducker *et al.* 1981), but was similar to the proportion observed at comparable intakes of LMM supplement and where animals grazed small paddocks (Wheeler *et al.* 1980; Dixon and Petherick 1996; Dixon *et al.* 1998). The lower variability in supplement intake among animals offered concentrate and molasses-based supplements (CV range 23–43%) than those offered LMM supplements (CV range 52–103%) in experiment 1 is in agreement with the results reported by Dixon and Petherick (1996), and appears to be associated with the higher voluntary intake of the former supplements rather than the type of supplement (Dixon *et al.* 1998). The similar proportion of non-eaters and CV in intake of LMM supplement in phase 4 of experiment 1 and experiment 2, despite of the large differences in the number of cattle in the paddock groups (9–11 *v.* 44–48 head), suggests that within this range the number of cattle in a herd may not be an important factor determining the proportion of non-eaters or variability in supplement intake.

As well as the variation in the supplement intake among animals on the day when lithium-labelled supplement was offered, there was also large variation over time in intake of LMM supplement in the present study. High variability between days and weeks in voluntary intake of LMM supplements has been reported previously (Morris *et al.* 1980; Rocks *et al.* 1982; Weber *et al.* 1992; Tait and Fisher 1996). In the present study, some of the changes in intake of LMM supplement appeared to be associated with rain. This is consistent with previous observations of weather on intake of block supplements (Weber *et al.* 1992) and observations and anecdotal reports on both research stations and commercial properties. Regardless of the reasons for this variation in voluntary intake of supplement, the variation within a group on a specific day and with time may tend to be additive and result in large variation in intake of supplementary nutrients by an individual animal. This is likely to be particularly important for urea supplements where high variation in supplement intake may substantially reduce the efficiency of utilisation of the supplementary nitrogen. The present study suggests that prior exposure to supplements or increased handling of the cattle are not likely to reduce the variation in intake of supplementary nutrients. However, choosing a supplement with a high voluntary intake to provide the same supplementary nutrients may reduce variability.

Difficulties occurred during the present studies with the use of lithium-labelled supplement to measure intake of LMM supplement by individual animals. First, when lithium chloride (Suharyono *et al.* 1991) was mixed with the LMM supplement the mixture became moist (DM content 805 g/kg) with a changed texture, presumably due to the hydroscopic nature of this lithium salt absorbing atmospheric moisture in a humid tropical environment. Thus, to minimise changes in the supplement that might modify its acceptability to the cattle, in later experiments the supplements were labelled with lithium sulfate. Second, during experiment 1 the intake of lithium-labelled LMM was less than half the intake of non-labelled supplement during the preceding 3–4 days. This low intake may also have been associated with changes in the supplement feeding routine, because the lithium-labelled supplement was available for only a restricted interval and/or novel characteristics of the labelled supplement. However, low intake of lithium-labelled supplement would only have introduced error if the reductions in intake differed among animals. The fact that the variability in supplement intake and the proportion of non-eaters did not differ markedly between experiments when LMM supplements were offered suggests that consistent estimates of variability in supplement intake were obtained.

Voluntary intake of supplements following initial acceptance

Supplements offered *ad libitum* are clearly only one of an array of potential foods which may be selected by the grazing ruminant. Thus, once supplements have been recognised and accepted as food, their voluntary intake is presumably influenced by the degree of preference of the animal for the supplement compared with preferences for the various forages and components of forages. Numerous factors are known to influence the preferences for, and the intake of, various forages, forage components and supplements by grazing ruminants (Heady 1964; Arnold *et al.* 1980; Matthews and Kilgour 1980; Provenza 1995, 1996). While there appear innate preferences, for example in selection of forage components consistent with achieving high and balanced intakes of major nutrients, there is extensive evidence that acquired preferences and aversions, social learning, facilitation and experience are also important. Prior experiences with a specific type, or types, of forage or supplement in the young ruminant may change the preference of animals for the specific feedstuff, and these changed preferences may persist for months or years. Prior experience of lambs has modified preference for specific species of plants (Burritt and Provenza 1990; Nolte *et al.* 1990; Squibb *et al.* 1990; Walker *et al.* 1992), concentrates (Green *et al.* 1984; Mottershead *et al.* 1985; Thorhallsdottir *et al.* 1990) and salt (Phillips *et al.* 1999). However, the present study indicated that although prior experience with cottonseed meal supplement, or in some situations LMM supplement, could increase voluntary intake of a LMM supplement, the effect lasted at most for only a few weeks. Thus, the previous experience of the cattle with supplements appeared not to have a major role in regulating voluntary intake of LMM supplements.

From evidence that sheep can regulate their voluntary intake of supplement to improve their balances of dietary protein and energy (Kyriazakis and Oldham 1993; Villalba and Provenza 1997) it seems likely that also cattle have this ability. It appears, however, that the voluntary intake of minerals is not regulated in the same manner (Coppock *et al.* 1976; Muller *et al.* 1977; Pamp *et al.* 1977). In the present experiments it is likely that nitrogen was the first limiting dietary component of the weaners grazing dry-season pasture (Winks 1984; Dixon and Doyle 1996). Presumably, ingestion of urea in the LMM supplement would potentially have had positive post-ingestive consequences by increasing microbial fermentation and the supply of absorbed amino acids, and negative post-ingestive consequences as excessive rumen ammonia concentrations (Chalupa *et al.* 1979; Kyriazakis and Oldham 1993; Arsenos *et al.* 2000). In the present study, such conflicting post-ingestive consequences of urea in the LMM supplements may have been one reason for the large variation in voluntary intake of LMM supplements, both between experiments and among individuals (Kyriazakis and Oldham 1993; Arsenos and Kyriazakis 1999).

In conclusion, the results of the present study suggest that providing a concentrate supplement before weaning, or while cattle are held in yards following weaning, can improve the acceptance and reduce the variability of intake of concentrate supplements offered in the paddock after weaning. Also voluntary intake of a LMM supplement was increased in the short term, but not in the long term, by prior provision of a concentrate supplement.

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