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Studies on magnesium in ruminant nutrition

11.* Effect of lactation on the excretion of calcium and potassium by grazing monozygotic twin cows

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1. The excretion of calcium and potassium in urine, milk and faeces by grazing monozygotic twin cows has been determined at intervals throughout four grazing seasons.

2. In Expt 1 three sets of twins were used to study the variation within pairs in the excretion of Ca and K. It was found that the variation within pairs was non-significant and small, less than 5% of the overall mean, for all but one of the factors measured. The variation in urinary excretion of Ca within pairs was significant ($P < 0.05$) in 1962.

3. In Expt 2 the effects of lactation on the excretion of Ca and K by three sets of twins were studied over two grazing seasons. Only one of each of the twins was in milk at a time, each twin being in milk for one season.

4. Lactation increased ($P < 0.001$) urinary and faecal Ca in 1964 but not in 1965. The concentrations of Ca in the faeces were lower ($P < 0.01$) for lactating than for non-lactating cows.

5. Lactation increased ($P < 0.001$) the excretion of K in urine and faeces. Differences within pairs in faecal concentration were significant in 1964 ($P < 0.001$) and 1965 ($P < 0.01$), but the effect was not attributable to lactation.

6. Significant differences between pairs were found for urinary Ca and K in 1964 ($P < 0.05$) and for the concentration of K in faeces in both years ($P < 0.01$ or $P < 0.001$).

7. In 1964 greatest total excretions of Ca were found in June and July and of K in May, whereas in 1965, although the differences between periods for Ca and K were significant ($P < 0.001$), there were no obvious seasonal trends.

8. Mean intakes of Ca and K by the cows have been calculated from the estimated dry-matter intake of herbage and the Ca and K content of the cut herbage and compared with total excretion in urine, milk and faeces. The differences between intake and excretion differed between periods ($P < 0.001$); for Ca, negative values were greatest in July and August in 1964 but not in 1965 and for K the values were small in July and large and positive in May, September and October in both years. The differences between lactating and non-lactating cows were significant for Ca ($P < 0.001$) and K ($P < 0.01$) in 1964. Selective grazing was considered to be the main factor responsible for these differences.

There has been little interest in the past in the role of potassium in ruminant nutrition since the possibility of a dietary deficiency of K, especially in grazing animals, is remote. The effects of high intakes of K on the metabolism of other essential inorganic elements were not considered until Kemp & t'Hart (1957) and Butler *et al.* (1963) described an association between the ratio, K content: calcium and magnesium content in herbage and the incidence of grass tetany. Attempts to define the relationship between K intake and serum Mg were generally unsuccessful although it became well established that high K intakes reduced the availability of dietary Mg (Meyer & Steinbeck, 1960; Kemp, Deijs, Hemkes & van Es, 1961). In more recent studies a marked effect of high intakes of K on serum Mg and the onset of tetany in sheep at low dietary intakes of Mg has been found (Suttle & Field, 1969).

Information on the relative intakes of K, Ca and Mg by grazing ruminants at

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different times of the year would be of importance in a study of the aetiology of hypomagnesaemic tetany. Balance trials cannot be carried out at pasture, but much indirect information on the intake of these elements may be obtained by recording the excretion of these elements in urine and faeces (see Field, 1967). The preceding paper (Field, 1970) describes the excretion of Mg and faecal dry matter (DM) by grazing lactating and non-lactating monozygotic cattle twins. Corresponding values for excretion of Ca and K are presented here.

EXPERIMENTAL

The design of the two experiments, the animals, diets and methods for the collection of excreta and for the preparation of samples for chemical analysis were the same as those given in the preceding paper (Field, 1970). The methods of analysis for Ca and K in the samples of urine and faeces were those used previously (Field, 1964) Samples of herbage were treated in the same manner as faeces. The concentration of Ca in milk was determined in a trichloroacetic acid filtrate (White & Davies, 1958) and that of K with a flame photometer by the method of Have & Mulder (1957). The statistical methods were the same as those given in the preceding paper (Field, 1970).

RESULTS

Expt 1

The mean excretion (g/day) of Ca and K in urine (UCa, UK), milk (MCa, MK) and faeces (FCa, FK) by the individual cows is given in Table 1. The differences within twins were small, less than 5% of the overall mean, and non-significant for all factors measured except UCa. For the latter, the differences were significant ($P < 0.05$) in

Table 1. *Mean output of calcium and potassium in urine (U), in milk (M) and faeces (F) (g/day) by the individual cows in 1962 and 1963*

(Values for twin pairs AB, CD, EF and GH)

			A	B	C	D	E	F	G	H	SE
1962	Ca	U	5·21	6·13	6·61	5·88	9·27	8·39	—	—	0·51
		M	11·8	11·4	21·5	21·8	22·7	19·8	—	—	0·41
		F	59·3	61·0	100·7	97·5	85·0	87·4	—	—	2·88
		T*	76·3	78·5	129	125	117	116	—	—	2·95
	K	U	202	213	203	200	198	190	—	—	8·87
		M	14·2	14·2	32·2	32·2	27·2	23·2	—	—	0·53
		F	45·4	49·4	39·4	37·8	30·0	27·6	—	—	1·47
		T*	262	277	275	270	255	241	—	—	9·50
1963	Ca	U	3·27	1·57	4·28	5·96	—	—	2·46	2·75	0·59
		M	14·6	14·5	23·3	23·2	—	—	21·1	21·1	0·85
		F	43·5	42·2	71·8	67·1	—	—	67·8	66·5	2·84
		T*	61·4	58·3	99·4	96·3	—	—	91·4	90·4	3·99
	K	U	304	335	284	282	—	—	240	209	9·12
		M	18·4	18·9	36·0	33·2	—	—	26·4	31·2	1·50
		F	55·3	49·0	45·0	40·3	—	—	49·3	51·0	2·42
		T*	378	403	365	355	—	—	316	291	10·10

* Total = (U+M+F).

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Table 2. *Mean concentration of calcium and potassium in milk (M) (mg/100 ml) and in faeces (F) (g/100 g dry matter) excreted by individual cows in 1962–1965*

(Values for twin pairs AB, CD, EF and GH)

			A	B	C	D	E	F	G	H	SE
1962	Ca	M	121	115	116	117	126	128	—	—	0·94
		F	1·32	1·33	1·84	1·86	2·12	2·24	—	—	0·057
	K	M	148	140	172	173	154	154	—	—	0·991
		F	0·975	1·05	0·720	0·715	0·748	0·698	—	—	0·028
1963	Ca	M	118	117	114	114	—	—	115	113	1·09
		F	1·33	1·37	1·81	1·73	—	—	1·82	1·86	0·054
	K	M	147	153	176	174	—	—	143	144	2·51
		F	1·69	1·60	1·14	1·04	—	—	1·33	1·42	0·049
1964	Ca	M	—	94·8	92·6	—	—	—	—	89·5	2·07
		F	1·84	1·69	1·66	1·98	—	—	1·91	1·71	0·048
	K	M	—	144	162	—	—	—	—	143	2·66
		F	0·919	0·916	0·841	0·808	—	—	0·873	1·14	0·036
1965	Ca	M	91·0	—	—	91·6	—	—	—	—	0·44
		F	1·22	1·39	1·43	1·22	—	—	—	—	0·051
	K	M	160	—	—	172	—	—	—	—	1·67
		F	1·12	0·909	0·789	—	—	—	—	—	0·036

1962 but not in 1963, the coefficients of variation being 15·6 and 23·0 in 1962 and 1963 respectively.

The differences between twins were significant for each of the factors measured in both years with the single exception of UK in 1962. These findings reflect the large differences in milk yield and live weight between twins and the feeding of concentrates to only two of the pairs. The content of Ca in the concentrates (0·93–1·45 g/100 g DM) was always much higher than that of the samples of cut herbage. The differences in UCa between twins appeared not to be related to milk yield or TCa and may be genetically determined.

The values for the mean concentration of Ca and K in milk and in faeces excreted by the individual cows in 1962 and 1963 are given in Table 2. Of the differences in concentration of Ca and K in milk within twins, only those for pair AB in 1962 were significant ($P < 0·05$). On the other hand, differences between twins were significant ($P < 0·01$) in both 1962 and 1963. Differences between periods were significant ($P < 0·01$) for Ca in both 1962 and 1963, whereas those for K were significant ($P < 0·001$) only in 1962. There were, however, no well-defined seasonal trends. The concentration of Ca and K in faeces was not significantly different within twins in 1962 and 1963.

Expt 2

Herbage. The values for the concentration of Ca, Mg and K in the samples of herbage are given in Table 3. From July onwards there was a significant correlation ($P < 0·01$) between the values of Ca and Mg in each sample taken in 1964 and in 1965. In 1964 high values were found in June for Ca and in May for Mg. Values for the concentration of K were low in June and July and high in May and October.

Excretion of Ca. The mean excretion (g/day) of UCa and FCa in 1964 and 1965 is given in Table 4 for the individual cows and in Table 5 for the lactating and non-lactating cows in each collection period.

The differences within and between sets of twins in UCa were highly significant ($P < 0·001$) in 1964. The lactating twin excreted more Ca than its non-lactating twin, the mean values were 2·34 and 1·46 g/day respectively. The differences between periods were significant ($P < 0·05$) in 1964 but not in 1965, but there were no seasonal trends.

The differences within twins in FCa were significant ($P < 0·001$) in 1964. The values were higher for the lactating than for the non-lactating twin, the mean values being 72·7 and 63·5 g/day respectively. In 1965 a similar difference was found for pair AB ($P < 0·025$) but not for pair CD. There were no significant differences between sets of twins in either 1964 or 1965. Differences between periods in FCa were significant in 1964 ($P < 0·001$) and in 1965 ($P < 0·05$). There was no marked seasonal trend in FCa except that the values tended to be low in May 1964.

The differences within pairs in the concentration of Ca in faeces were significant in 1964 ($P < 0·001$) and in 1965 ($P < 0·01$); the values for the lactating cows were lower than those for their non-lactating twins (Table 2). The mean values for the lactating and non-lactating cows were, respectively, 1·69 and 1·91 in 1964 and 1·22 and 1·41 g/

100 g DM in 1965. The difference between periods was highly significant ($P < 0·001$) in both years; the values ranged from 1·49 to 2·39 in 1964 and from 1·01 to 1·54 in 1965.

The differences within pairs in the total excretion of Ca in urine, milk and faeces (TCa) were significant in 1964 ($P < 0·001$) and in 1965 ($P < 0·01$). The values for

Table 3. *Concentration (g/100 g dry matter) of calcium, magnesium and potassium in the samples of herbage cut from the sward, periods* 1–12

	1	2	3	4	5	6	7	8	9	10	11	12
					1964							
	May	May	June	June	July	July	Aug.	Aug.	Sept.	Sept.	Oct.	Oct.
Ca	0·39	0·48	0·73	0·60	0·39	0·36	0·35	0·27	0·50	0·40	0·51	0·48
Mg	0·20	0·21	0·18	0·12	0·11	0·13	0·12	0·09	0·14	0·14	0·19	0·17
K	3·78	4·30	2·16	1·78	1·72	2·13	2·16	1·81	3·27	3·61	4·15	2·99
					1965							
				June	July	July	Aug.	Aug.	Aug.	Sept.	Sept.	
Ca	—	—	—	0·34	0·33	0·43	0·46	0·53	0·45	0·49	0·48	
Mg	—	—	—	0·09	0·07	0·12	0·13	0·16	0·16	0·16	0·15	
K	—	—	—	2·03	2·24	2·31	2·55	2·61	3·00	3·37	3·49	

Table 4. *Mean excretion (g/day) of calcium and potassium in urine (U), milk (M), faeces (F) by the individual cows in* 1964 *and* 1965

(Values for twin pairs AB, CD and GH)

			A	B	C	D	G	H	SE
1964	Ca	U	1·08	1·90	2·64	2·07	1·23	2·47	0·23
		M	—	11·0	15·0	—	—	16·0	0·37
		F	66·8	75·0	70·5	65·0	58·8	72·7	2·41
		T*	67·9	87·9	88·1	67·1	60·0	91·2	2·41
	K	U	189	263	247	180	157	245	7·20
		M	—	16·8	26·8	—	—	25·9	0·59
		F	33·2	40·4	35·2	26·0	26·7	47·1	1·97
		T*	222	320	309	206	184	318	7·60
1965	Ca	U	1·61	1·54	2·58	1·80	—	—	0·26
		M	10·4	—	—	12·7	—	—	0·46
		F	55·8	48·3	52·5	52·2	—	—	2·09
		T*	67·8	49·8	55·1	66·7	—	—	1·98
	K	U	245	201	192	246	—	—	6·64
		M	18·4	—	—	23·7	—	—	0·83
		F	52·1	31·9	29·2	31·9	—	—	1·45
		T*	316	233	221	302	—	—	6·34

* Total = (U+M+F).

the lactating cows were greater than those for the non-lactating cows, the mean values were, respectively, 89·1 and 65·0 g/day in 1964 and 67·2 and 52·4 g/day in 1965. The differences between sets of twins in TCa were not significant in either year. Highest values in 1964 were found in June and July, but in 1965 there was no seasonal pattern.

Excretion of K. The mean excretion (g/day) of UK, MK and FK in 1964 and 1965 is given in Table 4 for the individual cows and in Table 6 for the lactating and non-lactating cows in each collection period. The differences within twins in UK were

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Table 5. *Mean excretion of calcium in urine (U), milk (M) and faeces (F) (g/day) by the lactating (L) and non-lactating (nL) cows in 1964 and 1965, periods 1–12*

		1 May	2 May	3 June	4 June	5 July	6 July	7 Aug.	8 Aug.	9 Sept.	10 Sept.	11 Oct.	12 Oct.
1964 L*	U	1·61	1·03	3·12	1·96	2·82	2·82	1·97	2·75	2·23	2·36	1·84	3·55
	M	20·8	16·3	16·8	14·9	14·5	13·4	10·9	12·0	13·5	15·0	10·6	9·37
	F	55·4	65·0	86·2	80·5	92·8	86·9	76·7	59·8	67·7	65·8	77·9	58·3
	T	77·8	82·3	106	97·4	110	103	89·6	74·5	83·4	83·2	90·4	71·2
nL*	U	1·63	1·16	3·05	2·10	1·29	1·42	1·54	1·17	1·00	0·94	1·22	1·01
	F	56·8	67·5	75·0	59·3	83·0	69·2	58·5	57·4	61·8	67·7	58·2	48·0
	T	58·4	68·7	78·1	61·4	84·3	70·6	60·0	58·5	62·8	68·6	59·4	49·0
					June	July	July	Aug.	Aug.	Aug.	Sept.	Sept.	
1965 L†	U	—	—	—	1·11	1·27	2·22	1·52	2·61	1·81	0·580	2·49	
	M	—	—	—	13·2	11·6	12·4	12·0	12·7	12·5	9·98	7·97	
	F	—	—	—	47·5	50·6	61·5	47·0	56·6	58·1	56·2	54·0	
	T	—	—	—	61·8	63·5	76·1	60·5	71·9	72·4	66·8	64·5	
nL†	U	—	—	—	2·18	1·76	2·90	1·66	2·35	2·00	2·02	1·56	
	F	—	—	—	47·8	47·9	48·7	40·5	60·3	57·4	49·5	51·0	
	T	—	—	—	50·0	49·7	51·6	42·2	62·6	59·4	51·5	52·6	

* Three cows. † Two cows.

The SES for the values of U, M, F and T were 0·45, 0·74, 4·82, and 4·82 in 1964 and 0·52, 0·92, 4·18 and 3·95 g/day in 1965 respectively.

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Table 6. *Mean excretion of potassium in urine (U), milk (M) and faeces (F) (g/day) by the lactating (L) and non-lactating (nL) cows in 1964 and 1965, periods 1–12*

			1	2	3	4	5	6	7	8	9	10	11	12
			May	May	June	June	July	July	Aug.	Aug.	Sept.	Sept.	Oct.	Oct.
1964	L*	U	467	418	278	238	216	216	216	186	212	199	207	169
		M	33·5	28·9	30·1	25·0	25·2	26·6	18·9	21·1	21·1	17·4	15·0	15·3
		F	49·0	56·3	40·3	38·0	35·0	35·3	34·0	29·7	43·3	40·3	50·7	39·0
		T	549	503	348	301	276	277	269	237	276	257	273	223
	nL*	U	323	320	202	180	157	154	132	120	128	153	135	100
		F	42·7	47·7	27·7	22·7	22·0	22·7	21·0	19·7	28·7	33·7	26·3	27·0
		T	336	368	230	203	179	177	153	140	157	187	161	127
						June	July	July	Aug.	Aug.	Aug.	Sept.	Sept.	
1965	L†	U	—	—	—	304	279	201	168	255	285	253	221	
		M	—	—	—	24·3	21·2	22·8	22·0	22·2	22·9	19·3	13·7	
		F	—	—	—	35·5	57·0	41·0	41·5	35·0	36·0	41·0	49·0	
		T	—	—	—	364	357	265	231	312	344	313	284	
	nL†	U	—	—	—	232	208	173	137	210	239	204	167	
		F	—	—	—	25·0	40·5	27·5	26·5	25·5	29·5	33·5	36·5	
		T	—	—	—	257	248	200	163	235	268	237	203	

* Three cows. † Two cows.

The SEs for the values of U, M, F and T were 14·40, 1·17, 3·95, and 15·21 in 1964 and 13·27, 1·66, 2·89 and 12·69 g/day in 1965 respectively.

significant ($P < 0.001$) in both years, the lactating ones excreting more K than the non-lactating. The mean values (g/day) for the lactating and non-lactating cows were, respectively, 252 and 175 in 1964 and 245 and 196 in 1965. In 1964 the differences between twins in UK were significant ($P < 0.01$) and the values increased with increasing weight of the cows. The differences between periods were highly significant ($P < 0.001$) in both years. In 1964 values were highest in May (382 g/day), fell rapidly in June (198 g/day) and then remained relatively constant (135–186 g/day). There was no similar seasonal trend in 1965 when the collection periods started only at the end of June.

The differences within pairs in FK were highly significant ($P < 0.001$) in 1964 and 1965, the lactating twin excreting more K than its non-lactating twin. The mean values (g/day) for the lactating and non-lactating twins were respectively 40·9 and 28·6 in 1964 and 42·0 and 30·5 in 1965. The differences between sets of twins were significant in 1964 ($P < 0.01$) and in 1965 ($P < 0.001$). The differences between periods in FK were highly significant ($P < 0.001$) in both years. In 1964 values were high in May and September and there was a significant correlation ($r = 0.796$, $P < 0.01$) between the mean values for FK and UK in each collection period. In 1965 high values were again observed in September. Differences within and between pairs in concentration of K in faeces were significant in 1964 ($P < 0.001$) and 1965 ($P < 0.01$) but the differences within pairs were not attributable to lactation (Table 2).

The differences within pairs in total excretion of K (TK) were highly significant ($P < 0.001$) in 1964 and in 1965, the lactating twin excreting more K than its non-lactating twin. The mean values (g/day) for the lactating and non-lactating cows were respectively 316 and 203 in 1964 and 309 and 227 in 1965. The differences between sets of twins were significant ($P < 0.05$) in 1964 but not in 1965. The differences between periods were highly significant ($P < 0.001$) in both years.

Estimated intake of Ca and K. The mean value for the estimated intake (I) of an element by a group of cows in a collection period was obtained by using the method and results for DM intake of the cows given in the preceding paper (Field, 1970). The values obtained for ICa and IK for the lactating and non-lactating cows in 1964 and 1965 are given in Table 7. For comparison, the values for the total excretion of Ca and K are given in the same table. Statistical analysis of the values for ICa – TCa and IK–TK for each cow in each period showed that the differences within twins were significant for Ca ($P < 0.001$) and for K ($P < 0.01$) in 1964. The overall mean values for ICa – TCa were negative and greater for the lactating than for the non-lactating cows. For K the corresponding differences were reversed. The mean values (g/day) for the lactating and non-lactating cows were, respectively, –27·6 and –17·2 for Ca and 59·4 and 93·6 for K. The differences between periods in ICa – TCa and IK – TK were significant in 1964 ($P < 0.001$) and 1965 ($P < 0.01$). For Ca, negative values were greatest in July and August in 1964 but not in 1965. For K the values were small, either negative or positive, in July and large and positive in May, September and October in both years. The differences between sets of twins were not significant for either element in either year.

Table 7. *A comparison of the estimated intake (I) (g/day) of calcium and potassium by lactating (L) and non-lactating (nL) cows with the corresponding total excretion (T) (g/day) in urine, milk and faeces in 1964 and 1965, periods 1–12*

			1 May	2 May	3 June	4 June	5 July	6 July	7 Aug.	8 Aug.	9 Sept.	10 Sept.	11 Oct.	12 Oct.
1964 L*	Ca	I	51·8	81·5	109	86·7	52·8	45·5	45·1	30·1	63·7	48·3	66·2	54·1
		T	77·8	82·3	106	97·4	110	103	89·6	74·5	83·4	83·2	90·4	71·2
	K	I	502	730	323	257	233	269	279	202	430	436	539	337
		T	549	503	348	301	276	277	269	237	276	257	273	223
nL*	Ca	I	45·1	67·0	86·1	63·7	39·3	32·7	32·2	22·8	52·0	43·2	47·6	41·0
		T	58·4	68·7	78·1	61·4	84·3	70·6	60·0	58·5	62·8	68·6	59·4	49·0
	K	I	437	600	255	189	173	194	199	153	340	390	387	255
		T	366	368	230	203	179	177	153	140	157	187	161	127
						June	July	July	Aug.	Aug.	Aug.	Sept.	Sept.	
1965 L†	Ca	I	—	—	—	44·7	44·3	50·5	56·6	63·6	57·7	55·3	59·2	
		T	—	—	—	61·8	63·5	76·1	60·5	71·9	72·4	66·8	64·5	
	K	I	—	—	—	267	301	271	314	232	385	380	430	
		T	—	—	—	364	357	265	231	312	344	313	284	
nL†	Ca	I	—	—	—	39·0	36·9	43·6	44·7	52·8	48·9	41·2	43·8	
		T	—	—	—	50·0	49·7	51·6	42·2	62·6	59·4	51·5	52·6	
	K	I	—	—	—	233	250	234	248	260	326	283	318	
		T	—	—	—	251	248	200	163	235	268	237	203	

* Three cows. † Two cows.

The SEs for Ca were 3·95 and 4·13 and for K 20·4 or 19·9 g/day in 1964 or 1965 respectively.

DISCUSSION

The effect of lactation in increasing the total excretion of Ca and K may be due simply to the lactating twin eating more herbage than its non-lactating twin (Field, 1970). However, the lactating twin may have lost more Ca or K from its body (Forbes, Black, Braman, Frear, Kalenburg, McClure, Swift & Voris, 1935) or selected herbage of a different chemical composition (Elliott, Fokkema & French, 1961). The effects of factors other than DM intake can be seen from the comparison given in Table 8 of the mean ratios of the total excretion of each element by the lactating and non-lactating twin in each set with the corresponding ratio for DM intake (Field, 1970). The differences between the ratio for total intake and for DM intake were significant for Ca in 1964 ($P < 0.01$) and for K in 1964 ($P < 0.001$) and 1965 ($P < 0.001$) and represent an additional excretion of 5 and 2·7 Ca g/day and of 52 and 28 K g/day in 1964 and 1965 respectively. Forbes *et al.* (1935) found that cows on average lost 6·5 g Ca/day during the first 3 months of lactation, were in balance during the next 3 months and gained 3·4 g/day during the next 3 months and when dry. Thus changes in body content between lactating and dry cows could account for the additional Ca excreted by the lactating cows and possible effects of lactation on Ca concentration in the diet selected were probably unimportant. On the other hand, the additional excretion of K by the lactating twin is too great to be accounted for in this way and is probably due to the lactating twin selecting herbage higher in K than its non-lactating twin. Since K is confined more to the leaf than the stem, this finding suggests that more leaf than stem is selected by a lactating than by a dry cow. Elliott *et al.* (1961) have shown that herbage selected by lactating cows had 13 and 32% more digestible organic matter and digestible crude protein respectively than that selected by dry cows.

Table 8. *Mean values for the ratio of the excretion of calcium, and potassium, and of dry-matter intake* (I_{DM}) *by each lactating cow in relation to its non-lactating twin in* 1964 *and* 1965

	1964			1965		
Pair	Ca	K	I_{DM}	Ca	K	I_{DM}
AB	1·29	1·45	1·23	1·36	1·36	1·31
CD	1·32	1·50	1·30	1·21	1·37	1·16
GH	1·52	1·73	1·37			

The effect of lactation was to reduce the faecal concentration of Ca in both 1964 and 1965. Since there was no evidence for lactating cows selecting herbage of a lower concentration of Ca or of lower digestibility (Field, 1970), the above effect was probably due to a higher apparent absorption of dietary Ca. Whether this greater apparent absorption reflects true absorption or a reduced excretion of Ca into the gastro-intestinal tract from the body remains to be seen. However, the finding that endogenous Ca excretion is independent of Ca intake (Visek, Monroe, Swanson & Comar, 1953; Lueker & Lofgreen, 1961) suggests that the former may be more probable.

The effect of lactation was to increase UCa in the lactating cows. This increase may be due in part to the increased intake of Ca, but little is known regarding the factors which control UCa in ruminants. That intake is not the sole factor is shown by the significant differences between sets of twins in UCa in 1964 and in 1965 without corresponding differences in total excretion of Ca. It seems surprising that lactating cows which may have to mobilize Ca from the skeleton for milk production should not have a more efficient mechanism than dry cows for reducing UCa.

The marked disparity between the values for the estimated intake and total excretion of Ca and K for the cows is similar to that doscribed for sheep (Field, 1967). The overall estimated intakes of the cows, expressed as a percentage of excretion, were 76·2 for Ca and 121 for K, whereas the corresponding values for sheep were 59 and 142. Furthermore, the seasonal variations in the differences between intake and excretion were also similar for sheep and cows. The differences were large and negative from June to October for Ca and large and positive in May and October for K for both sheep and cattle. Field (1967) has argued that the most probable explanation for these findings for sheep is selective grazing and that the values for total excretion are the best estimates available for the daily intake of these elements by the grazing sheep. The same arguments appear to apply in the present study and confirmation of this viewpoint comes from a comparison of the values for the estimated intake and total excretion of Ca by the lactating cows with the calculated Ca requirements of milking cows giving similar milk yields (Agricultural Research Council, 1965). Good agreement was found between requirements (74–100 g/day) and total excretion (71–100 g/day) but not for intakes (30–109 g/day). Both estimated intake and excretion of Ca of the dry cows were greater than their Ca requirements (18·4 g/day) (Agricultural Research Council, 1965). Owing largely, it seems, to the effects of selective grazing, the values for the ratio of K:(Ca+Mg) in total excretion, expressed in equivalents, were in general lower than those in cut herbage, especially in September and October, and lower for dry than for lactating cows.

The results from these experiments show clearly the great advantage of using monozygotic twins to study changes in the metabolism by dairy cows of the more important major minerals, especially in situations where there is little experimental control over dietary intake. They also help to increase the body of information which suggests that much of the large individual variation in the mineral metabolism of ruminants is under genetic control (Weiner, Field & Wood, 1969; Field, Weiner & Wood, 1969).

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