

Calcium digestibility in cows as influenced by the excess of alkaline ions over stable acid ions in their diets

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1. Statistical analyses were carried out on results obtained under strictly-controlled conditions in metabolism stalls with forty-one different rations fed to 127 adult non-pregnant dry cows, and with fourteen other different rations fed to thirty-five adult non-pregnant lactating cows that had calved 2–6 months earlier and whose daily milk production ranged from 11 to 20 kg.

2. Correlations between calcium digestibility and values for the sum of the alkaline ions sodium and potassium minus the sum of the stable acid ions chloride, sulphate and phosphate were calculated for all fifty-five experimental diets.

3. The results showed that the excess of the anions over the cations, in rations maintaining a positive Ca balance but not in rations allowing a negative Ca balance, increases the absorption of Ca from the intestine. Phosphorus, not alone but with chloride and sulphate, is the most important component of this effect.

The decisive influence of an excess of dietary calcium in the aetiology of milk fever was recently well established (Black, Capen & Arnaud, 1973; Black, Capen, Yarrington & Rowland, 1973). But a great number of cows, although fed on rations with a high Ca content, fail to retain sufficient amounts of Ca.

In a previous paper (Paquay, Lomba, Lousse & Bienfet, 1968), we showed that the fate of Ca in rations fed to adult dry or lactating but non-pregnant cows, although regulated in the intestine and influenced by the lactation Ca requirements, does not depend on the ingested amounts of Ca or of any other nutritive factor but on the nature itself of the components of the diets and their proportions in the diets. Rations containing cereals, especially barley, have from this point of view a particular beneficial effect.

The assumption that the alkali-alkalinity (according to Dishington (1975) alkali-alkalinity = (potassium + sodium) – (sulphate + chloride) (mequiv/d) of diets fed during the prepartum period was of overriding importance in determining Ca availability was made by Scandinavian workers (Ender & Dishington, 1970; Ender, Dishington & Helgebostad, 1971). In their view, a positive alkali-alkalinity reduced Ca absorption whereas a negative alkali-alkalinity increased the Ca balance. The possibility of inducing or preventing milk fever at successive parturitions in the same cow by altering, with a mixture of calcium chloride, aluminium sulphate and magnesium sulphate, the alkali-alkalinity of diets fed for 4 weeks prepartum was a particularly striking confirmation of their assumption (Dishington, 1975). In the present work, we used the extensive information obtained in metabolism stalls with adult non-pregnant cows given fifty-five different experimental diets which had already led us to interesting conclusions about the fate of dietary Ca (Paquay *et al.* 1968), phosphorus (Lomba, Paquay, Bienfet & Lousse, 1969) and chloride (Paquay, Lomba, Lousse & Bienfet, 1969), in order to investigate whether the influence of the dietary alkali-alkalinity recorded at parturition by Dishington (1975) also exists with diets fed to non-pregnant cows at times other than at the 'drying-up' period. We also tried to find out whether this effect could play a part in the explanation of the beneficial effect of cereal-containing rations on the Ca balance.

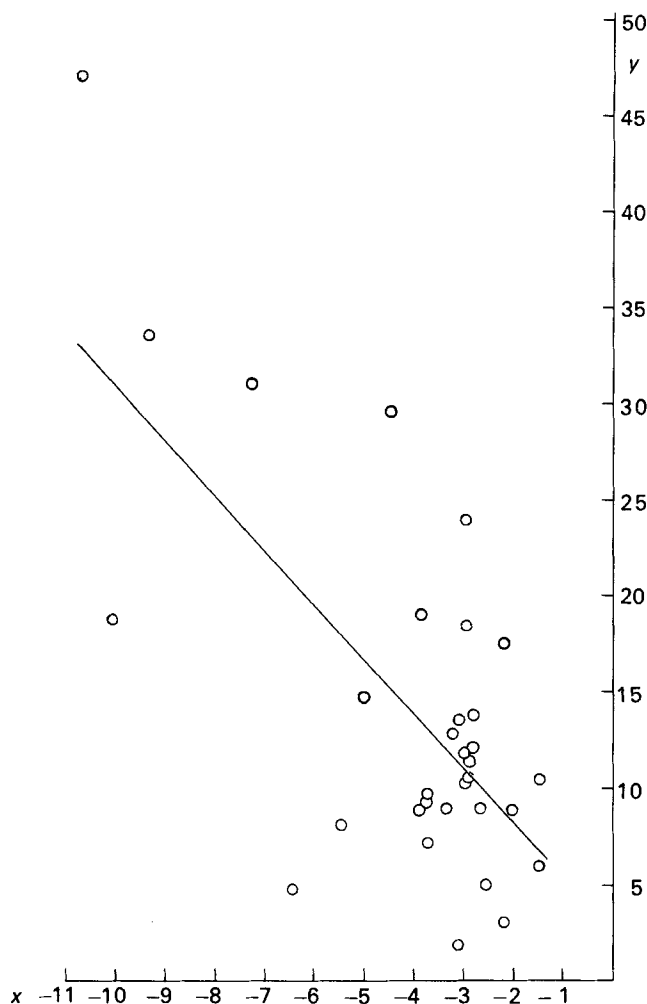


Fig. 1. Correlation between digestible calcium (g) (y) and daily digested amounts (mequiv ($\times 10^3$)) of sodium, potassium, chloride, sulphate and phosphate (x) expressed as $(Na + K) - (Cl + S + P)$ for dry and lactating cows given thirty-two different rations inducing a positive Ca balance (for details, see p. 427). Regression equation: $y = 2.6283 - 2.8279 x$ ($r = -0.6767$, $P < 0.001$, $n = 32$).

EXPERIMENTAL

A detailed description of the diets and of the experimental methods was given previously (Paquay *et al.* 1968). Fifty-five different rations were used. For each of these experimental rations eighty-one values were collected, each of which was a mean value calculated for all the cows in each trial. The values included for the principal constituents of the ration, daily intake, ration content, digestibility, urinary excretion and nutrient balance. All the results were expressed in mequiv/cow per d. The trials were conducted in metabolism stalls on adult non-pregnant cows: 127 cows were dry and thirty-five cows were lactating, 2–6 months after parturition, and with a daily milk production of 11–20 kg.

The correlation coefficients between the amounts of digested Ca (g) and each of the following expressions containing the daily ingested amounts of sodium, potassium, chloride, sulphate and phosphate ions: $(Na^+ + K^+) - (Cl^- + SO_4^{2-} + PO_4^{3-})$ ($(Na + K) - (Cl + S + P)$) and

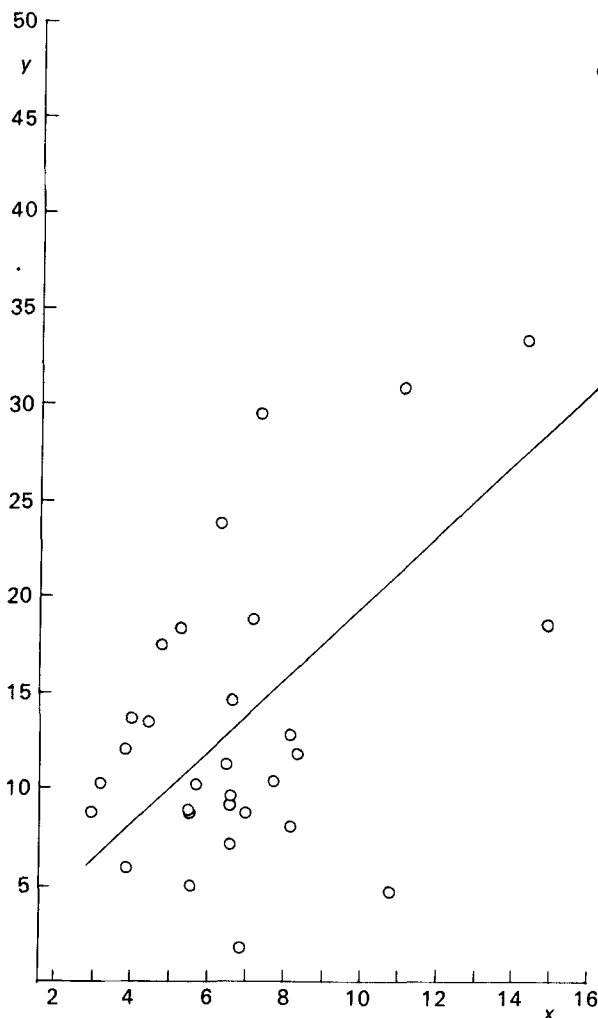


Fig. 2. Regression between digestible calcium (g) (y) and daily digested amounts (mequiv ($\times 10^3$)) of chloride, sulphate and phosphate (x) expressed as (Cl+S+P) for dry and lactating cows given thirty-two different rations inducing a positive Ca balance (for details, see p. 427). Regression equation: $y = 0.6407 + 1.8902x$ ($r = 0.6220$, $P < 0.001$, $n = 32$).

$(\text{Na}^+ + \text{K}^+) - (\text{Cl}^- + \text{SO}_4^{2-})$ ($(\text{Na} + \text{K}) - (\text{Cl} + \text{S})$) were calculated. To eliminate any influence due to variations in ingested amounts of Ca or daily intakes of $(\text{Na}^+ + \text{K}^+)$, partial correlation was used.

RESULTS

Since no difference at all was found between dry and lactating cows, it was not necessary to separate these two groups in the present paper. The most important results are summarized in Figs. 1 and 2 and Table 1.

Table 1 shows that there was a significant negative correlation between digestible Ca and $(\text{Na} + \text{K}) - (\text{Cl} + \text{S} + \text{P})$ for all the rations ($r = -0.309$, $P < 0.05$). When the rations were divided into two groups according to Ca balance, the correlation coefficient was highly significant for the rations inducing a positive Ca balance ($r = -0.676$, $P < 0.01$) but was less significant for the rations with a negative Ca balance.

Table 1. Correlation between digestible calcium and daily intakes of sodium, potassium, chloride, sulphate and phosphate ions at constant Ca and (Na + K) intakes for dry and lactating cows given fifty-five different rations

(Expressions for daily intakes of ions: $(\text{Na}^+ + \text{K}^+) - (\text{Cl}^- + \text{SO}_4^{2-} + \text{PO}_4^{3-})$
 $((\text{Na} + \text{K}) - (\text{Cl} + \text{S} + \text{P}))$ and $(\text{Na}^+ + \text{K}^+) - (\text{Cl}^- + \text{SO}_4^{2-}) ((\text{Na} + \text{K}) - (\text{Cl} + \text{S}))$)

	<i>n</i>	Partial correlations with constant intake of:		
		Ca	(Na + K)	Ca and (Na + K)
For all the rations:	55			
(Na + K) - (Cl + S)		0.106	0.122	
(Na + K) - (Cl + S + P)		-0.309	0.091	
For negative Ca balance:	23			
(Na + K) - (Cl + S)		0.506	0.202	
(Na + K) - (Cl + S + P)		0.057	0.230	
For positive Ca balance:	32			
(Na + K) - (Cl + S)		0.023	0.235	
(Na + K) - (Cl + S + P)		-0.676	-0.623	-0.630
(Cl + S)		0.420	0.288	0.342
(Cl + S + P)		0.622	0.486	0.630
(Na + K)		-0.319		-0.538
				0.165
				0.369

There was a significant positive correlation between digestible Ca and $(\text{Na} + \text{K}) - (\text{Cl} + \text{S})$ but only with rations giving a negative Ca balance and this correlation coefficient was not significant when eliminating the effect of dietary Ca by partial correlation.

The correlation coefficient ($r = 0.676$, $P < 0.01$) between digestible Ca and $(\text{Na} + \text{K}) - (\text{Cl} + \text{S} + \text{P})$, in rations inducing a positive Ca balance, was also highly significant when eliminating, by partial correlation, the influence of the daily intakes of Ca ($r = 0.623$, $P < 0.01$), of $(\text{Na} + \text{K})$ ($r = 0.630$, $P < 0.01$), or simultaneously of Ca and $(\text{Na} + \text{K})$ ($r = 0.538$, $P < 0.01$). The correlation coefficients between digestible Ca and expressions which included Ca and magnesium in the sum of the cations were studied but none was found significant. No difference was observed between the cereal-containing rations and the other rations.

DISCUSSION

The theory that the alkali-alkalinity of diets fed to pregnant cows during the 'drying-up' period influences Ca absorption from the intestine (Ender *et al.* 1971) received further support from the work of Dishington (1975). We have found also that the proportion of the alkaline ions relative to the stable acid ions of diets fed to adult dry or lactating but non-pregnant cows could modify the fate of dietary Ca. Indeed, with rations maintaining a positive Ca balance, there was a highly significant negative correlation coefficient between digestible Ca and $(\text{Na} + \text{K}) - (\text{Cl} + \text{S} + \text{P})$, which was also highly significant when eliminating the effect of dietary Ca by partial correlation.

The situation was quite different with rations allowing only a negative Ca balance. It appeared, in this instance, that the cows had no other purpose than meeting their Ca requirements and that it was only when they were absorbing amounts of Ca which were in excess of their needs that the effect of alkali-alkalinity of the diet was recorded. The expression giving the most significant correlation, in our experimental conditions, was different

from that established by Dishington (1975) in his attempts to prevent milk fever. In fact, its second term included phosphate as well as chloride and sulphate.

Is there a predominant factor? If so, it could not be a single component of the rations. As reported in a previous paper (Paquay *et al.* 1968), apart from a parallel between Ca and Mg in their absorption and utilization, the correlation coefficients between Ca digestibility and all the nutritive factors were not significant. However, the present study showed that they were highly significant with the association of some of these factors: (Cl+S), (Cl+S+P), and (Na+K)–(Cl+S+P).

Considering that the correlation coefficient ($r = 0.676$, $P < 0.01$) between digestible Ca and (Na+K)–(Cl+S+P) was also highly significant when eliminating, by partial correlation, the influence not only of dietary Ca but also at the same time of (Na+K) intakes ($r = 0.538$, $P < 0.01$), we may conclude that the most important factor is the association (Cl+S+P).

Furthermore, comparison of the results obtained either with (Cl+S+P) or with (Cl+S) indicated that the prevailing influence was that of P. Indeed, the only active expression was that containing P, even when eliminating the influence of the intakes of Ca and (Na+K) by partial correlation ($r = 0.538$, $P < 0.02$). However, P does not act on Ca absorption directly by itself, as found previously (Paquay *et al.* 1968; Lomba *et al.* 1969), but together with chloride and sulphate. However, it is interesting to note that the alkali-alkalinity of the diets, although capable of modifying the intestinal Ca absorption in pregnant as well as in non-pregnant cows, in certain circumstances, does not explain the Ca availability of the rations. Its effect was in fact recorded when the Ca balance was positive and never with rations allowing only a negative Ca balance, and this effect is not affected by the Ca requirements of lactation since no difference was found between dry and lactating cows. It does not explain the beneficial effect on the Ca balance of cereal-containing rations.

Nevertheless, it was worthwhile considering the effect of dietary alkali-alkalinity. As long as the intrinsic control mechanisms of Ca absorption from the gut remain to be elucidated, the best way of diminishing the incidence of parturient paresis might be, in addition to feeding low-Ca rations prepartum (Boda & Cole, 1954), the feeding of relatively acid diets as in the trials conducted in Norway.

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