Changes in Erythrocyte Mg, Na and K Concentrations in Late Pregnancy and Early Lactation and their Relationship With Subsequent Fertility and Milk Production in Dairy Cows

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With 3 figures and 3 tables

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Summary
Weekly blood samples were collected from 62 Friesian and Jersey cows between 8 weeks before and 8 weeks after calving and analysed for erythrocyte Mg (EMg), Na (ENA) and K (EK). No particular trend was observed for EMg concentration in both the pre-partum and post-partum periods. The concentrations of ENa decreased (P < 0.05) and that of EK increased (P < 0.05) after calving. Significant (P < 0.01) weekly and between cow variations were observed for both ENa and EK concentrations. The mean EMg concentration was correlated with milk production rank (r = 0.533, P < 0.01) and services/conception (r = -0.458, P < 0.05) in the pre-partum and post-partum periods, respectively. The mean EK concentrations was correlated with milk production rank in both the pre-partum (P < 0.05) and post-partum (P < 0.01) periods. The relationship observed between EMg and EK concentrations and fertility/milk production rank implies that these parameters could be included in the metabolic profile testing parameters.

Key words: EMg, ENa, EK, fertility, milk production

Introduction
The basic causes of reproduction and productive problems in a herd are not always apparent and herd management, nutritional and pathological factors can be involved. Many attempts have been made to detect such problems before their onset by the measurement of blood components (Sommer, 1975; Parker and Blowey, 1976; Lee et al., 1978; Manston and Allen, 1981). However, blood analyses have not demonstrated a consistent relationship to fertility and milk production in dairy cows (Parker and Blowey, 1976; Rowlands, 1980). There is thus a need to explore other blood parameters that could be used in detecting reproductive and productive problems in dairy herds.

In a prolonged low grade Mg deficiency there can be a very profound drop in the erythrocyte Mg (EMg) concentration without much changes in the plasma Mg (PMg) concentration (Ellin et al., 1971). The level of EMg could therefore be a better indicator of prolonged subclinical Mg deficiency, and this has been reported to be associated with low
milk production and low milk fat content in dairy cows (Young and Rys, 1977; Young et al., 1979), impaired lactation and lowered fertility in rats (Wang et al., 1971; Harley et al., 1976). In Jersey cows, low EK levels were found to be associated with a higher milk production than high EK levels (Rasmussen et al., 1974). This suggests that EK concentrations could be related to milk production in dairy cows.

This work was carried out to investigate the changes that occur in erythrocyte Mg, Na and K concentrations in late pregnancy and early lactation and the relationship of such changes with subsequent fertility and milk production in dairy cows.

Material and Methods

Experimental Animals

Sixty-two Friesian and Jersey cows aged between 2½ to 9 years from one herd and on the same feeding regime were used. The cows were grazed on irrigated rye grass and clover pastures during the dry winter months and in the wet summer months were grazed on tropical pastures (mainly Rhodes, Kikuyu, and Green panic grasses). The milking cows were supplemented with a concentrate mixture containing sorghum grain and meat meal. The cows were observed twice daily during the morning and afternoon milking periods for oestrus, were artificially inseminated and the dates of services recorded. Milk production rank for each cow calculated by the method of Wayne et al. (1977), was obtained from the Queensland Department of Primary Industries, Dairy Division, Herd Production Recording Scheme.

Blood Collection and Analysis

Weekly blood samples were collected between 9.00 and 10.30 a.m. from the coccygeal blood vessels of each cow from 8 weeks before to 8 weeks after calving. The blood samples were analysed for haematocrit (by the micro-haematocrit method), plasma Mg (PMg) (by atomic absorption spectroscopy), plasma Na (PNa) and K (PK) (by flame emission photometry), erythrocytes Mg (EMg), Na (ENA) and K (EK) concentrations by the method given below.

The erythrocyte Mg, Na and K concentrations were estimated indirectly using haemolysed blood. The haemolysed blood prepared by diluting 0.35 ml of blood with 1.0 ml of deionized water was centrifuged at 3,000 rpm for 10 minutes to remove the cell debris. The supernatant was used for determination of EMg, ENa and EK concentrations. The EMg concentration was determined by an atomic absorption spectroscopy using the method of Willis (1960). The ENa and EK concentrations were determined in an emission flame photometer model 343 (Instrumentation Lab Inc. Lexington, Mass., U.S.A.). The actual concentrations of Mg, Na and K in the erythrocytes were calculated using the following formula.

\[
\text{EMg (mmol/l)} = \frac{3.9 \times \text{HBMg value} - (1-\text{PCV}) \times \text{PMg value}}{\text{PCV}}
\]

Where 3.9 = Dilution factor
HBMg value = Haemolysed blood Mg value (mmol/l)
PMg value = Plasma Mg value (mmol/l)
PCV = Packed cell volume (l/l)

The same formula was also used for the calculation of the actual ENa and EK concentrations.

Statistical Analysis

The weekly mean concentrations of each parameter were measured and compared by the Student’s t-test. The weekly and the between cow variations for each of the blood parameters were tested by analyses of variance.

The changes in the concentration of each blood parameter for the periods 8 weeks before and 8 weeks after calving were expressed as slopes (linear regression coefficients). The slopes were obtained by individually regressing each blood parameter on weeks in each of the two time periods. The simple correlation coefficients between the overall pre-partum and post-partum mean values and mean slopes were found for each blood parameter and services/conception, days open and milk production rank.
Table 1. The mean pre-partum and post-partum concentrations (x) and slopes (b) of erythrocyte Mg, Na and K of the dairy cows

<table>
<thead>
<tr>
<th>Blood parameter</th>
<th>Pre-partum</th>
<th>Post-partum</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMg (mmol/l)</td>
<td>1.10 ± 0.01</td>
<td>1.19 ± 0.01</td>
</tr>
<tr>
<td></td>
<td>0.02 ± 0.01</td>
<td>0.06 ± 0.03</td>
</tr>
<tr>
<td>ENa (mmol/l)</td>
<td>100.5 ± 4.12</td>
<td>93.1 ± 1.46</td>
</tr>
<tr>
<td></td>
<td>2.37 ± 1.16</td>
<td>5.49 ± 1.18</td>
</tr>
<tr>
<td>EK (mmol/l)</td>
<td>31.9 ± 0.31</td>
<td>33.4 ± 0.61</td>
</tr>
<tr>
<td></td>
<td>0.09 ± 0.04</td>
<td>0.26 ± 0.03</td>
</tr>
<tr>
<td>PCV (l/l)</td>
<td>0.32 ± 0.03</td>
<td>0.29 ± 0.03</td>
</tr>
<tr>
<td></td>
<td>-0.03 ± 0.02</td>
<td>-0.25 ± 0.04</td>
</tr>
</tbody>
</table>

Results

The pre-partum and post-partum mean concentrations and slopes of EMg, ENa and EK are shown in Table 1, and changes in the concentrations of these parameters before and after calving are shown in Figs. 1—3.

The mean EMg concentrations did not change significantly in either the pre-partum or the post-partum periods (Fig. 1). However, the mean concentrations did increase significantly (P < 0.05) from 8 weeks pre-partum to 8 weeks post-partum. The concentrations of EMg varied significantly (P < 0.05) between weeks (Table 2).

The mean ENa and EK concentrations decreased and increased, respectively (P < 0.05) in the post-partum period (Figs. 2 and 3). The ENa concentrations varied significantly (P < 0.05) between cows and between weeks in both the pre-partum and post-partum periods (Table 2). EK concentrations also showed significance between cow

![Fig. 1. Changes in erythrocyte magnesium (EMg), (Mean ± SE) concentrations in dairy cows 8 weeks before to 8 weeks after calving](image-url)
Table 2. The mean squares (M.S.) from the analysis of variance of erythrocyte Mg, Na and K concentrations in the dairy cows (n=62)

<table>
<thead>
<tr>
<th>Pre-partum</th>
<th>weekly concentration</th>
<th>cow M.S.</th>
<th>error M.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMg (mmol/l)</td>
<td>2.1</td>
<td>231.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>58.6</td>
</tr>
<tr>
<td>ENa (mmol/l)</td>
<td>141.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1,617.1&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>46.4</td>
</tr>
<tr>
<td>EK (mmol/l)</td>
<td>1.17</td>
<td>1,695.1&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>26.1</td>
</tr>
</tbody>
</table>

Post-partum

| EMg (mmol/l)        | 106.2                | 207.3<sup>a</sup> | 61.8       |
| ENa (mmol/l)        | 133.5<sup>b</sup>    | 638.3<sup>ab</sup> | 43.9       |
| EK (mmol/l)         | 117.0<sup>b</sup>    | 1,547.9<sup>ab</sup> | 38.5       |

<sup>a</sup> P < 0.05, <sup>ab</sup> P < 0.01.

variations (P < 0.05) and weekly mean variations (P < 0.05), but the latter variations were
significant only in the post-partum period (Table 2).

The fertility indices studied were services/conception (Mean ± SE = 1.97 ± 0.19) and
days open (Mean ± SE = 91.6 ± 4.79). The mean concentrations and slopes of EMg, ENa
and EK were not related to fertility except for the post-partum mean EMg concentration
which was negatively (P < 0.05) related to both services/conception and days open (Table
3). The milk production rank (Mean ± SE = 117.1 ± 4.44) was significantly related to the
pre-partum EMg (r = 0.533, P < 0.01) and EK (r = 0.423, P < 0.05) concentrations and the
post-partum EK concentrations (r = 0.699, P < 0.01).

Discussions

The increase in EMg concentrations from 8 weeks before to 8 weeks after calving may
have been due to an increased production of reticulocytes and young erythrocytes as a
result of the decreased packed cell volume (Table 1). Reticulocytes and young erythrocytes
contain higher Mg concentrations than mature erythrocytes, and their numbers increase
with a decrease in haematocrit levels (BERNSTAIN, 1959; GINSBURG et al., 1962; TIMMS
and MURPHY, 1980). The significant variations of EMg concentrations between cows and not

Fig. 2. Changes in erythrocyte sodium (ENa) (Mean ± SE) concentrations in dairy cows 8 weeks
before to 8 weeks after calving.
Fig. 3. Changes in erythrocyte potassium (EK) (Mean ± SE) concentrations in dairy cows 8 weeks before to 8 weeks after calving.

between weeks shows that EMg concentrations differ between cases but do not fluctuate from week to week in an individual cow.

The decrease in ENa concentrations and the increase in EK concentrations could have been due to increased production of reticulocytes and young erythrocytes as suggested also for EMg. Reticulocytes and young erythrocytes showed low ENa and high EK concentrations (Evans, 1963; Timms and Murphy, 1980). Weekly variations in ENa concentrations have also been reported previously in cattle (Evans and Phillipson, 1957; Christinaz and Schatzmann, 1972). The significant weekly variations in EK concentrations in the post-partum period only indicates that EK concentrations show greater variations during lactation than during gestation. Previous work in sheep showed that EK concentrations varied significantly between lactating ewes and not between dry ewes (Evans, 1963). The between cow differences in EK concentrations have been attributed to inheritance of genes that control EK concentrations (Evans and Phillipson, 1957).

The concentration of EMg after calving was negatively related to services/conception and days open. This indicates that cows with high EMg concentrations after calving had

Table 3. The simple correlation coefficients (r) between erythrocytes Mg, Na and K concentrations and services/conception, days open and milk production rank in the dairy cows

<table>
<thead>
<tr>
<th>Pre-partum</th>
<th>Services/conception (r)</th>
<th>days open (r)</th>
<th>production rank (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMg (mmol/l)</td>
<td>(§)</td>
<td>0.182</td>
<td>0.211</td>
</tr>
<tr>
<td></td>
<td>(b)</td>
<td>0.111</td>
<td>0.121</td>
</tr>
<tr>
<td>ENa (mmol/l)</td>
<td>(§)</td>
<td>0.142</td>
<td>0.187</td>
</tr>
<tr>
<td></td>
<td>(b)</td>
<td>0.102</td>
<td>0.09</td>
</tr>
<tr>
<td>EK (mmol/l)</td>
<td>(§)</td>
<td>0.158</td>
<td>0.202</td>
</tr>
<tr>
<td></td>
<td>(b)</td>
<td>0.122</td>
<td>0.115</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Post-partum</th>
<th>Services/conception (r)</th>
<th>days open (r)</th>
<th>production rank (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMg (mmol/l)</td>
<td>(§)</td>
<td>-0.458*</td>
<td>-0.349*</td>
</tr>
<tr>
<td></td>
<td>(b)</td>
<td>0.123</td>
<td>0.119</td>
</tr>
<tr>
<td>ENa (mmol/l)</td>
<td>(§)</td>
<td>0.157</td>
<td>0.170</td>
</tr>
<tr>
<td></td>
<td>(b)</td>
<td>0.060</td>
<td>0.091</td>
</tr>
<tr>
<td>EK (mmol/l)</td>
<td>(§)</td>
<td>0.187</td>
<td>0.197</td>
</tr>
<tr>
<td></td>
<td>(b)</td>
<td>0.082</td>
<td>0.120</td>
</tr>
</tbody>
</table>

§ = Mean, b = Slope, * P < 0.05, ** P < 0.01.
fewer services/conception and fewer days open. Low tissue and erythrocyte Mg concentrations could be contributory factors to the damage of the products of conception (HURLEY et al., 1976; SEELING, 1980). There was a positive relationship between milk production and the pre-partum EMr concentration. This relationship indicates that high EMr concentrations before calving were associated with higher milk production rank. Since the cows were from the same farm and were on the same diet and management, it is possible that high EMr concentration during gestation is a feature of high yielding cows. The negative relationships between milk production rank and EK concentrations indicate that high yielding cows had or maintained lower EK concentrations than the low yielding cows. In a herd of Jersey cows, low EK concentrations were found to be associated with high milk production (RASMUSSEN et al., 1974). Low EK concentration may therefore be a characteristic of high yielding dairy cows.

The relationships observed between the erythrocyte parameters and fertility and milk production indicate that EMr and EK concentrations could be important parameters in the metabolic profile testing in dairy cows.

Acknowledgement

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Zusammenfassung

Veränderungen der Mg-, Na- und K-Konzentrationen in den Erythrozyten während der Spätrüchtigkeit und frühen Laktation und ihre Beziehung zur Fruchtbarkeit und Milchleistung bei Milchkühen

Bei 62 Friesian- und Jersey-Kühen wurden im Zeitraum von 8 Wochen vor dem Kalben bis 8 Wochen nach dem Kalben wöchentlich Blutproben entnommen und auf den Mg- (EMr), Na- (ENA) und K- (EK) Gehalt der Erythrozyten untersucht. Für EMr zeichnete sich weder während der praem partum- noch während der post partum-Phase ein besonderer Trend ab. ENA nahm nach dem Kalben ab (p < 0,05), während EK zunahm (p < 0,05).

Sowohl für ENA als auch für EK ergab sich zwischen verschiedenen Wochen und Tieren eine signifikante Variation (p < 0,01). In der praem und post partum-Phase war der mittlere Wert für EMr mit dem Milchleistungsgrad (r = 0,533, p < 0,01) und der Zahl der Besamungen pro Konzeption (r = -0,458, p < 0,05) korreliert. Die mittleren Werte für EK waren sowohl in der praem partum-Phase (p < 0,05) als auch in der post partum-Phase (p < 0,01) mit dem Milchleistungsgrad korreliert. Die zwischen EMr bzw. EK und der Fruchtbarkeit sowie dem Milchleistungsgrad beobachteten Beziehungen implizieren, daß diese Parameter für die Untersuchung des metabolischen Profils herangezogenen Parametern angefügt werden könnten.

References


SOMMER, H., 1975: Preventive Medicine in dairy cows. Veterinary Medical Reviews (Bayer) 1—42.


