INTERPRETATION of mineral research results may be complicated and inaccurate if physiological changes in experimental animals are not considered. Variations in bovine blood mineral levels have been partially explained by the effects of pregnancy, parturition, lactation, and age.

Pregnancy has been reported to have no effect on serum magnesium (Dishington, 1965), plasma calcium and inorganic phosphorus (Payne and Leech, 1964), or serum calcium and plasma inorganic phosphorus (Said et al., 1964). Decreased serum calcium and phosphorus with increased magnesium have been noted at or immediately following parturition (Allcroft and Green, 1934; Said et al., 1964; Sellers and Roepke, 1951). Plasma sodium, plasma potassium and serum magnesium did not change at parturition according to Dishington (1965) and Sellers and Roepke (1951).

Said et al. (1964) reported no age effect on serum calcium and inorganic phosphorus. A decrease in serum phosphorus with advancing age was observed by Anderson et al. (1930), Braun (1946), and McSherry and Grinyer (1954); in plasma by Payne and Leech (1964); and in whole blood by Johnson (1939). Shirley et al. (1967) reported an increase in phosphorus of approximately 1 mg. per 100 ml. of plasma at 15, 16, and 17 yr. of age. Plasma calcium decreased with age in studies of Payne and Leech (1964), Shirley et al. (1967) and in serum according to Vrkgula (1963) while Anderson et al. (1930) reported no change in serum calcium. A greater incidence of hypocalcemia and hypomagnesemia in older cows was noted by Moodie (1965). Vrkgula (1963) found lowered serum sodium and potassium levels with age. A lactation effect of lowered plasma inorganic phosphorus was observed by Payne and Leech (1964). A lower serum magnesium level was found by Bakker (1961) for high producing cows than for low producers.

Seasonal changes in plasma calcium and phosphorus were found by Shirley et al. (1967) with higher values in September than in March. In a study designed to evaluate commonly used sources of calcium and phosphorus, Ammerman et al. (1957) observed no treatment effects on plasma calcium and inorganic phosphorus following a depletion period.

The purpose of this study was to determine the apparently normal levels of five trichloracetic acid (TCA) soluble whole blood minerals and the variations observed with season, lactation, sire groupings and other selected physiological states.

Materials and Methods

Blood samples were taken the month prior to calving and each third month after calving during the following year from 236 Guernsey cows. Samples were taken in heparinized glass tubes by jugular vein puncture and stored in ice water following collection. Four ml. of whole blood were mixed with 36 ml. of 10% trichloracetic acid and centrifuged for 10 min. at 2,500 r.p.m. in a 40.6 cm. diameter International centrifuge. After centrifuging, the samples were filtered through Whatman No. 541 filter paper, and the filtrate was refrigerated at 4.4°C until analyzed for minerals.

Calcium was measured by emission flame photometry on a multichannel flame spectrometer using 50% ethanol solutions and strontium as an internal standard according to an unpublished method of Pickett (personal communication). A modification of the method of Sterges et al. (1950) was used for the phosphorus measurement. Sodium and potassium analyses were accomplished by emission flame photometry as given by Dean (1960). The method of Willis (1960) was used for the determination of magnesium by atomic absorption.

The data used in this study were not orthogonal to every statistical classification. This lack of balance for each classification made an orthogonal analysis impossible; however, the nonproportionality was probably typical of
BLOOD MINERAL COMPOSITION IN RUMINANTS

TABLE 1. TCA SOLUBLE MINERAL CONTENT OF WHOLE BLOOD (mg./100 ml.).

<table>
<thead>
<tr>
<th>Mineral</th>
<th>No. of samples</th>
<th>Range</th>
<th>Mean</th>
<th>S.E.</th>
<th>Variance within cows</th>
<th>Variance among cows</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>838</td>
<td>3.7-10.1</td>
<td>6.1</td>
<td>0.0276</td>
<td>0.4828</td>
<td>0.1546</td>
</tr>
<tr>
<td>Mg</td>
<td>833</td>
<td>1.7-4.3</td>
<td>2.3</td>
<td>0.0081</td>
<td>0.0478</td>
<td>0.0072</td>
</tr>
<tr>
<td>Ca</td>
<td>833</td>
<td>3.7-12.0</td>
<td>7.4</td>
<td>0.0260</td>
<td>0.5436</td>
<td>0.0238</td>
</tr>
<tr>
<td>Na</td>
<td>837</td>
<td>222-480</td>
<td>281.0</td>
<td>0.7489</td>
<td>459.9300</td>
<td>95.4900</td>
</tr>
<tr>
<td>K</td>
<td>888</td>
<td>19-170</td>
<td>52.0</td>
<td>0.3922</td>
<td>44.5500</td>
<td>84.7100</td>
</tr>
</tbody>
</table>

Inheritance were evaluated for each mineral. In each case, effects were tested with pooled within group cow to cow variation.

Results and Discussion

The range, mean and standard error for each mineral are presented in table 1. Correlation analyses (table 2) indicated a positive correlation of magnesium with calcium and potassium; calcium with sodium and potassium; and a negative correlation of sodium with potassium.

An analysis of variance of all data for month of pregnancy demonstrated a significant effect on phosphorus (P<.01), sodium (P<.10) and potassium (P<.025). These mineral concentrations are presented in table 3 for both the months of pregnancy and the month following parturition. The observed pregnancy effect on phosphorus is not in agreement with the report of Payne and Leech (1964) who reported no effect. Correlation analyses (table 2) gave a positive correlation of phosphorus and potassium and a negative correlation of sodium with month of pregnancy.

Significant effects of month of lactation were found for phosphorus (P<.005), magnesium (P<.005), calcium (P<.05) and sodium (P<.005). The means for each month of lactation are presented in table 4. Magnesium, calcium and potassium were negatively correlated with month of lactation (table 7) while sodium showed a positive correlation.

A comparison of mineral levels by months of pregnancy was made by dividing all data into two groups according to month of lactation. One group included all data while the other group included only data for lactation months 1, 2, 3, and 4. No significant month of pregnancy effects were observed during the first 4 mo. of lactation.
The data were compared for four seasons (quarters) of the year (season: 1, Jan., Feb., Mar., etc.). A seasonal effect on plasma calcium is in agreement with the report of Shirley et al. (1967) but differs in that no effect was observed for phosphorus. Quarter means for each of the seasons are presented in Table 5. Magnesium was lowest in the first quarter of the year and highest in the third quarter with means of 2.2 and 2.4 mg./100 ml., respectively. A mean of 7.6 mg./100 ml. for calcium in the third quarter followed a low of 7.2 mg./100 ml. in the second quarter. Sodium was constant in the first three quarters of the year with a high mean of 286 mg./100 ml. in the fourth quarter.

To determine if inheritance influenced mineral levels, the herd was divided into 17 sire groups for those sires having 10 or more daughters. The ranges in means for the various minerals according to sire groups were as follows: P, 5.8–6.6; Mg, 2.2–2.4; Ca, 7.1–7.6; Na, 268–286; and K, 45.2–61.2 mg./100 ml. Sire effects were significant (P<.005) for phosphorus, magnesium, sodium and potassium. Heritability estimates from half sib correlations were as follows: P, 0.33; Mg, 0.25; Na, 0.28; K, 0.59; and Ca, 0.02, with standard errors of 0.1190, 0.1013, 0.1084, 0.1809, and 0.0484, respectively.

The cows were divided into two groups by milk production levels of 2,721 to 4,535 and from 4,536 to 6,080 kg. of milk. The blood mineral means for each level of production were very similar. Correlation analyses (Table 7) indicated a positive correlation of magnesium and a negative correlation of potassium with milk production.

A multiple regression equation was fitted on data for each mineral and milk production.
TABLE 6. MEAN TCA SOLUBLE WHOLE BLOOD MINERALS BY AGE (mg./100 ml.)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>6.3a</td>
<td>6.0bc</td>
<td>6.3ab</td>
<td>5.8bed</td>
<td>6.0abc</td>
<td>5.6a</td>
<td>6.0bc</td>
<td>6.8a</td>
</tr>
<tr>
<td>S</td>
<td>0.049</td>
<td>0.060</td>
<td>0.078</td>
<td>0.076</td>
<td>0.088</td>
<td>0.112</td>
<td>0.121</td>
<td>0.082</td>
</tr>
<tr>
<td>K</td>
<td>50a</td>
<td>53a</td>
<td>51a</td>
<td>56a</td>
<td>53a</td>
<td>63a</td>
<td>52a</td>
<td>51a</td>
</tr>
<tr>
<td>SX</td>
<td>0.706</td>
<td>0.860</td>
<td>1.126</td>
<td>1.089</td>
<td>1.278</td>
<td>2.626</td>
<td>1.740</td>
<td>1.188</td>
</tr>
</tbody>
</table>

* Means within a given mineral having a common letter in their superscripts are not statistically different at $P<.05$. Multiple correlations ranged from .16 to .26, but in each case month of pregnancy, season of year, age of cow and month of lactation significantly reduced the variation in the data.

The calcium:phosphorus ratio was determined for each month of pregnancy and lactation. The ratio was larger during the first half of pregnancy with a maximum of 1.28 in the second month (table 3). The smallest ratio (1.14) occurred in the month following parturition. The last half of gestation was characterized by a relatively constant calcium level while phosphorus increased to the ninth month. The smallest ratio (1.14) was due primarily to a large drop in calcium which may be associated with the demands of early lactation.

A division of the animals into eight age groups showed a significant effect of age on phosphorus and potassium ($P<.01$). The young animals (18 to 30 mo.) demonstrated the highest mean phosphorus level (6.3 mg. %) and the lowest mean potassium (50 mg. %) as depicted in table 6. With the exception of two age groups (79 to 90 and 91 to 102 mo.), a phosphorus change from one age group to the next corresponded to an inverse change for potassium. An effect of age on phosphorus has been reported several times in the literature. The effect of age on potassium was also noted by Vrzgula (1963). In this study, age was negatively correlated with phosphorus and positively correlated with potassium (table 7).

TABLE 7. CORRELATION OF TCA SOLUBLE WHOLE BLOOD MINERALS WITH PHYSIOLOGICAL CONDITION

<table>
<thead>
<tr>
<th>Item</th>
<th>P</th>
<th>Mg</th>
<th>Ca</th>
<th>Na</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pregnancy, mo.</td>
<td>0.14*</td>
<td>-.02</td>
<td>-.06</td>
<td>-.12*</td>
<td>0.13*</td>
</tr>
<tr>
<td>Age</td>
<td>-.22*</td>
<td>-.04</td>
<td>.03</td>
<td>-.01</td>
<td>.07*</td>
</tr>
<tr>
<td>Lactation, mo.</td>
<td>0.02</td>
<td>-.15*</td>
<td>-.10*</td>
<td>0.10*</td>
<td>-.08*</td>
</tr>
<tr>
<td>Milk production</td>
<td>0.00</td>
<td>0.11*</td>
<td>0.01</td>
<td>0.05</td>
<td>-.13*</td>
</tr>
</tbody>
</table>

* $P<.05$.

**Summary**

Trichloracetic acid soluble whole blood minerals were measured each 3 mo. in samples from 236 Guernsey cows to determine mineral levels under herd conditions. The means observed were: P, 6.1; Mg, 2.3; Ca, 7.4; Na, 281 and K, 52 mg./100 ml. Positive correlations were found for Mg with Ca and K; and for Ca with Na and K; and a negative correlation for Na with K. Month of pregnancy affected P, Na, and K. Month of lactation was related to P, Mg, Ca, and Na.

Seasonal differences were shown for Mg, Ca and Na. Sire effects were significant for P, Mg, Na and K. Milk production was positively correlated with Mg and negatively correlated with K. The Ca:P ratio was largest during the first half of pregnancy. A small ratio of 1.14 in the second month of lactation was preceded in the first month and followed by an increased ratio in the third to the seventh month of lactation. A significant effect of age was found for P and K. A general inverse relationship was observed for P and K among age groups.

**Literature Cited**


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