A STUDY OF SOME ASPECTS OF THE METABOLIC PROFILE OF GRAZING DAIRY CATTLE IN NEW ZEALAND

A THESIS PRESENTED IN PARTIAL FULFILMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY
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CHAPTER V

RESULTS & DISCUSSION (PART B)

The samples used for this part of the investigation came from the Awaroa Research Farm on the Rangitaiki Plains. As the testing procedure and analytical procedures were in most respects identical to those used for Part A the results for Awaroa have been compared with the results obtained on the Massey units. The data for the latter were pooled for this purpose and a mean weighted for the number of observations calculated for each parameter.

Haematocrit

The haematocrit value for the Awaroa herd fell in between that for Unit 1 and Units 2 and 3 and the standard deviation for the Awaroa herd was lower than for the Massey herds (Tables IV:1 and V:1). This could be explained by the Awaroa herd receiving a more even level of feeding than the animals on the three Massey units as level of nutrition does influence the haematocrit (see earlier discussion p 152).

Haematocrit plotted against weeks from the start for the Awaroa herd (Fig. V:1) produced a biphasic curve similar to that obtained on the Massey units (Fig. V:2) with the start of the rise and the peak in the curve occurring earlier. This may be accounted for by climatic differences since the average temperature for this area, which is further north than Massey, is higher. As a result there could have been a direct effect from this higher temperature on the haematocrit and an indirect nutritional effect associated with earlier grass growth.

The plot for haematocrit against weeks in milk (Fig. V:3) appeared to duplicate the changes seen in the plot against weeks from the start. An increase in the standard deviation for the means of this curve, noted towards the end of lactation, was probably associated with few animals being sampled at that

TABLE V:1

MEANS AND STANDARD DEVIATIONS FOR THE AWAROA HERD TOGETHER WITH THE CALCULATED MEANS FOR THE THREE MASSEY UNITS AND A COMBINED MASSEY-AWAROA MEAN

		Awaroa		Massey*	Massey* and Awaroa
		$\bar{x}$	s.d.		
Haematocrit	%	25.5	2.3	26.0	25.9
Haemoglobin	g/100ml	-	-	10.3	-
Total protein	g/100ml	7.8	0.6	8.4	8.3
Albumin	g/100ml	3.4	0.6	3.4	3.4
Urea Nitrogen	mg/100ml	19.3	4.4	19.1	19.1
Glucose	mg/100ml	53.1	6.9	57.0	56.1
Sodium	m/Eq/l	140.5	6.1	-	-
Potassium	m/Eq/l	4.9	0.4	5.2	5.2
Magnesium	mg/100ml	2.5	0.4	2.1	2.2
Calcium	mg/100ml	8.7	2.0	10.1	-
Inorganic Phosphate	mg/100ml	5.6	1.4	6.0	5.9

* Means as calculated are weighted means for both the Massey (3 Units) and Massey and Awaroa means.

TABLE V:2 : PERCENTAGE OF VARIATION EXPLAINED (R^2) - AWAROA HERD

	Season	Lactation	Age
Haematocrit	3.9	3.9	8.0*
Haemoglobin	-	-	-
Total protein	4.0	7.2	0.0
Albumin	4.9	4.1	3.3
Urea Nitrogen	20.5**	15.4**	1.3
Glucose	12.8*	13.0**	1.3
Sodium	22.2**	20.5**	1.0
Potassium	15.2**	14.5**	0.0
Magnesium	24.1**	23.8**	6.9
Calcium	-	-	-
Inorganic Phosphate	16.2**	15.2**	3.7

Significance of multiple regression coefficient (R)

** $P < 0.01$

* $P < 0.05$

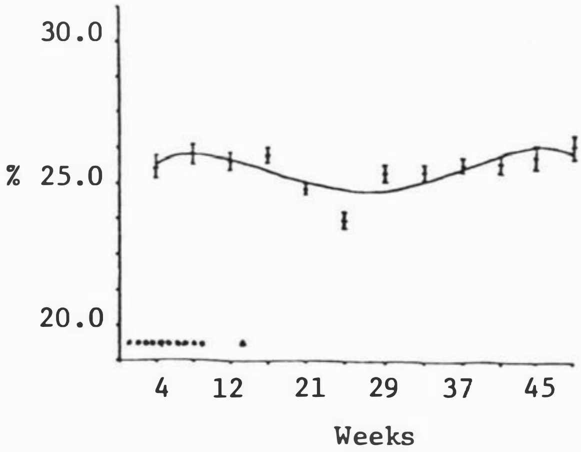

Figure V: I

Awaroa herd R.P.D.
Haematocrit
Time in 4 weeks intervals
(approx)

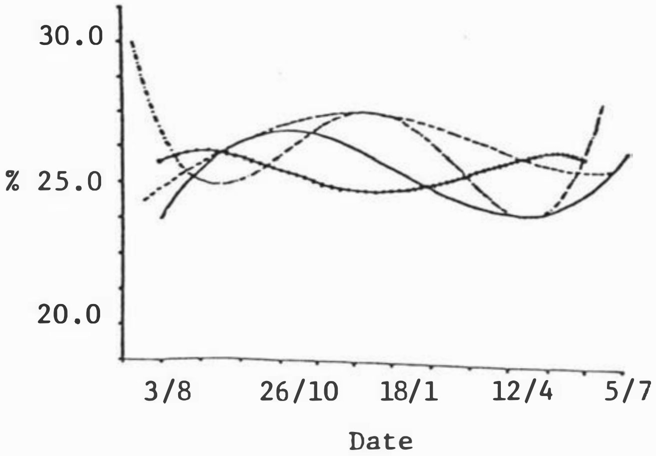

Figure V: 2

Awaroa herd and all 3 Massey herds
Haematocrit
Simultaneous plot by time

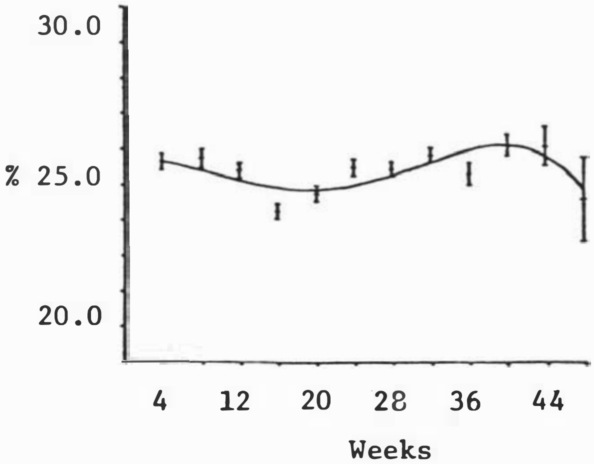

Figure V: 3

Awaroa herd R.P.D.
Haematocrit
Weeks in milk

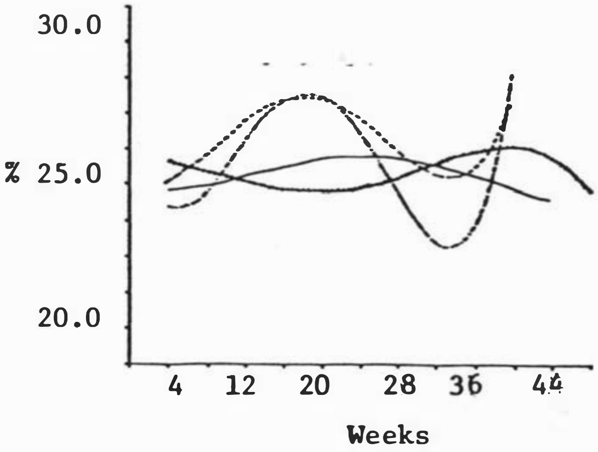

Figure V: 4

Awaroa herd and all 3 Massey herds
Haematocrit
Weeks in milk
Simultaneous plot

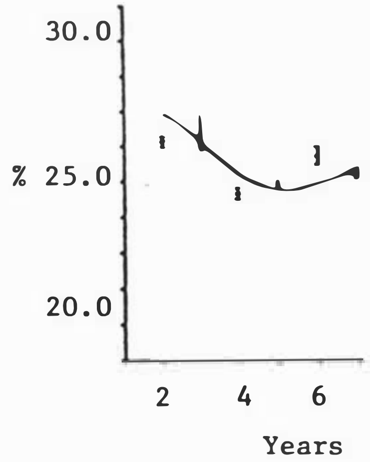

Figure V: 5

Awaroa herd R.P.D.
Haematocrit
Age

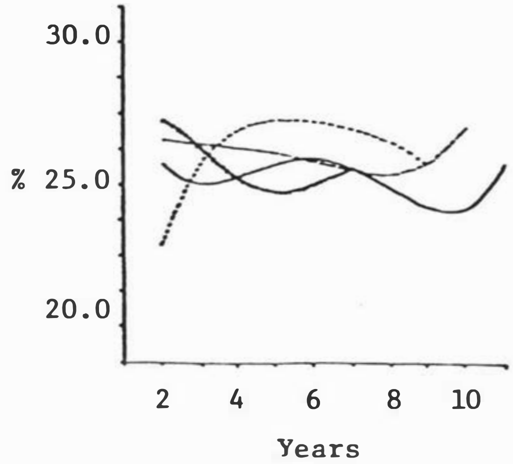

Figure V: 6

Awaroa herd & all 3 Massey herds
Haematocrit
Age
Simultaneous plot

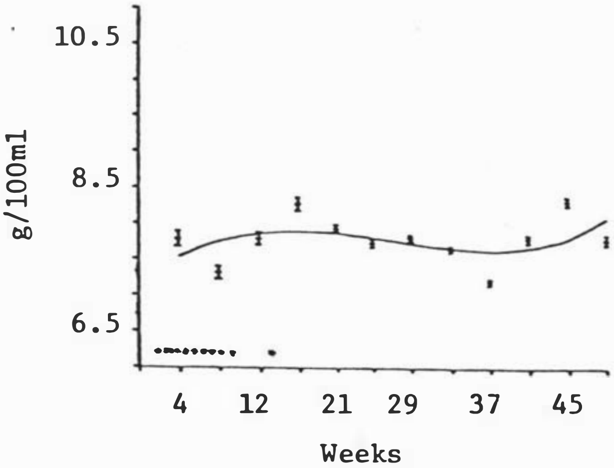

Figure V: 7

Awaroa herd R.P.D.
Total protein
Time in 4 week intervals(approx

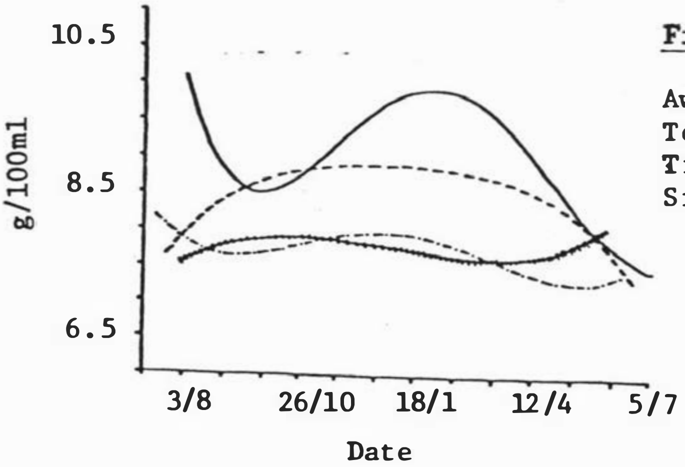

Figure V: 8

Awaroa herd & all 3 Massey herd
Total protein
Time in 4 week intervals
Simultaneous plot

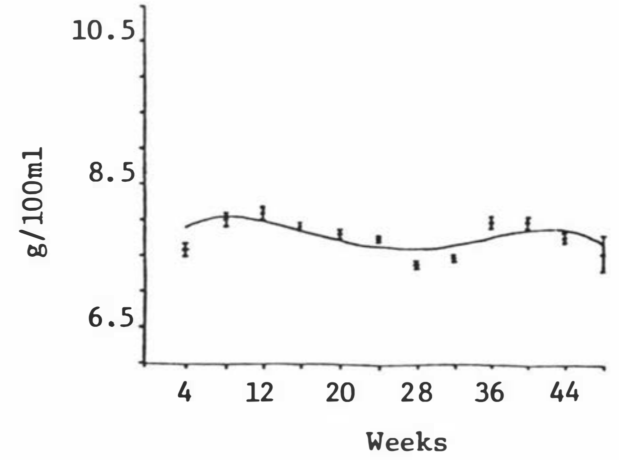

Figure V: 9

Awaroa herd R.P.D.
Total protein
Weeks in milk

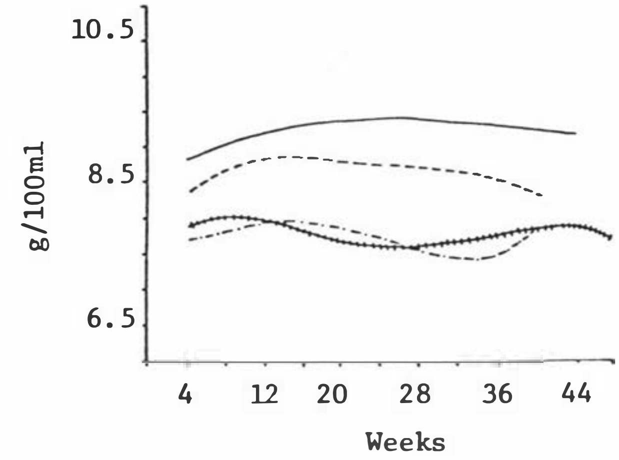

Figure V: 10

Awaroa herd & all 3 Massey herds
Total protein
Weeks in milk
Simultaneous plot

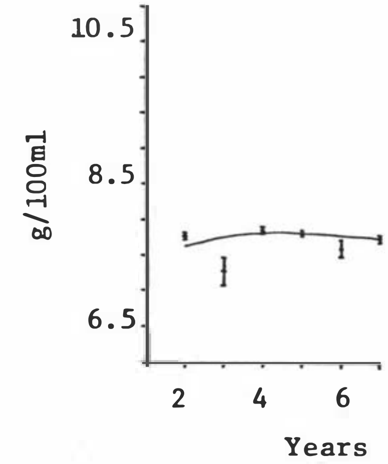

Figure V: 11

Awaroa herd R.P.D.
Total protein
Age

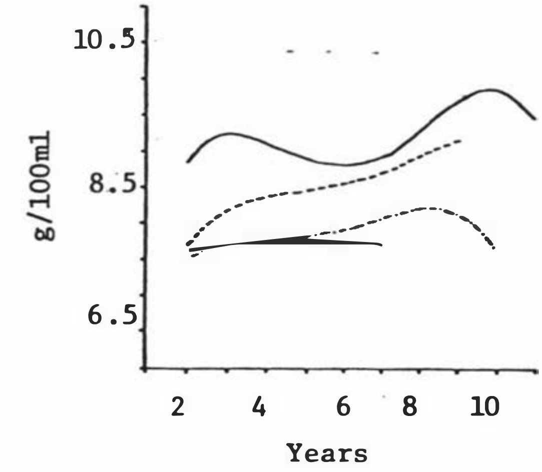

Figure V: 12

Awaroa herd & all 3 Massey herds
Total protein
Age
Simultaneous plot

stage (n=11 for the 44 week mean and n=2 for the 48 week mean compared with n=50 for the 4 week mean). The different shape of the Awaroa curve for the haematocrit, which fell from the beginning of lactation (Fig. V:4) has been recorded by overseas workers (Hewett, 1974; Rowlands *et al.*, 1975; Treacher *et al.*, 1976) and has been attributed to the demands of lactation; it was stated that the fall occurs regardless of the level of protein nutrition of the animal. Why this should have been the case on the Awaroa unit and not the Massey units cannot be satisfactorily explained. The percentage of variation explained by lactation was only 3.9% which was the same as that explained by season (Table V:2).

Age as a source of variation accounted for 8% of the total. Since this herd had only been recently acquired, and the ages for animals 6 years and over were not known, this plot (Fig. V:5) covered a relatively short age span. The indications from the curve were that there could have been a small decrease in haematocrit with increasing age, a trend not observed on the Massey units (Fig. V:6).

Haemoglobin levels were not estimated for the Awaroa data.

Total Protein & Albumin

The mean serum total protein level for the Awaroa herd was similar to that for Unit 3 and showed remarkably small fluctuations throughout the year (Table V:1; Figs. V:7-8). Serum albumin was even more stable throughout the sampling period and showed none of the fluctuations seen on the Massey units (Figs. V:13-14). The absence of fluctuations in these values suggested that protein supply was sufficient to sustain normal health and production.

Whether there was an insufficiency in respect of other components of the feed during the period of high milk production as suggested in the next section could not be resolved from the total protein and albumin data.

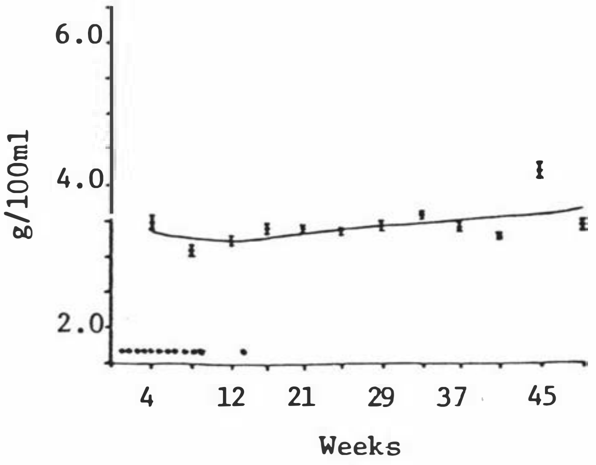

Figure V: 13

Awaroa herd R.P.D.
Albumin
Time in 4 week intervals(approx)

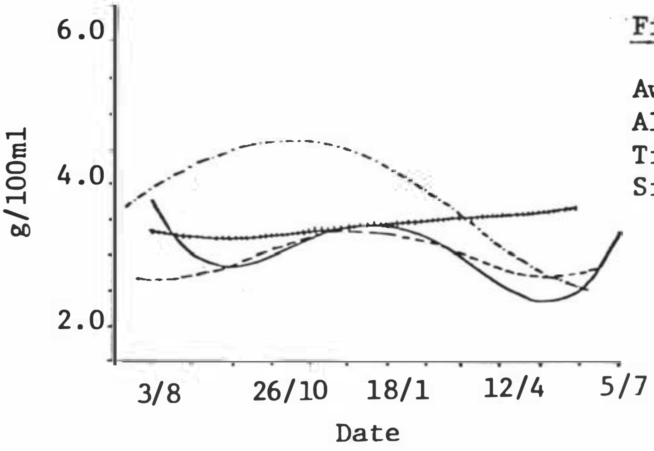

Figure V: 14

Awaroa herd & all 3 Massey herds
Albumin
Time in 4 week intervals
Simultaneous plot

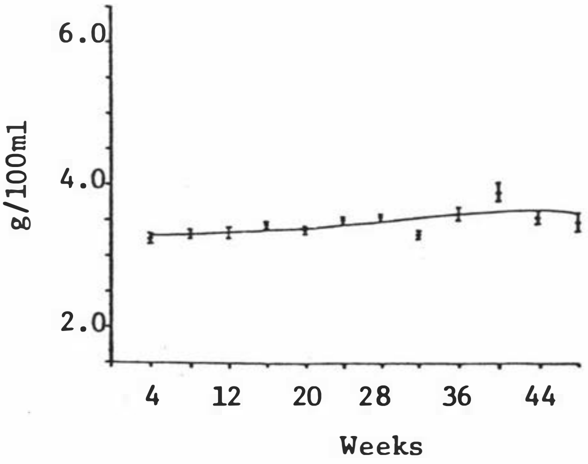

Figure V: 15

Awaroa herd R.P.D.
Albumin
Weeks in milk

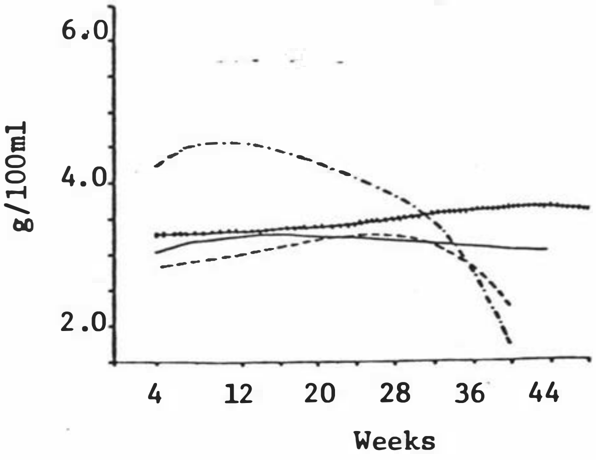

Figure V: 16

Awaroa herd & all 3 Massey herds
Albumin
Weeks in milk
Simultaneous plot

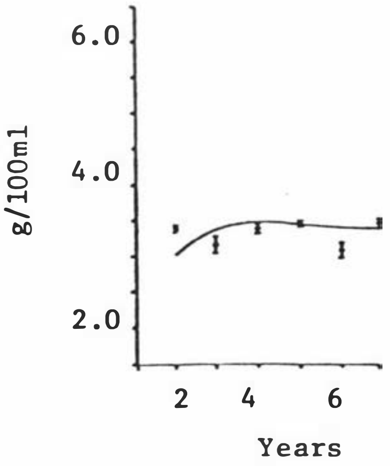

Figure V: 17

Awaroa herd R.P.D.
Albumin
Age

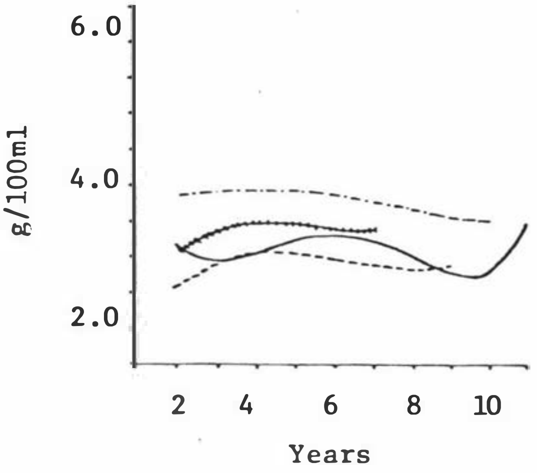

Figure V: 18

Awaroa herd & all 3 Massey herds
Albumin
Age
Simultaneous plot

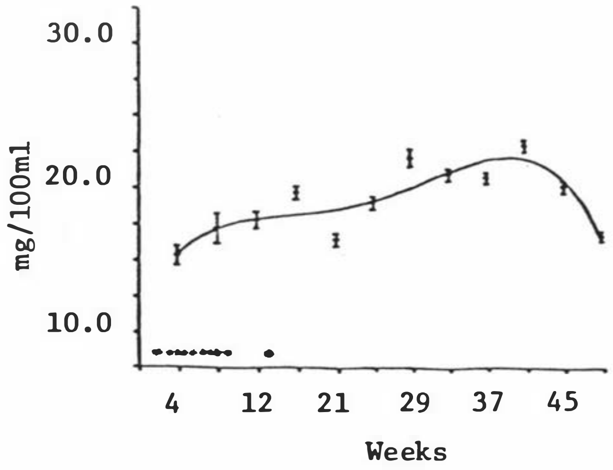

Figure V: 19

Awaroa herd R.P.D.
Urea nitrogen
Time in 4 week intervals(approx)

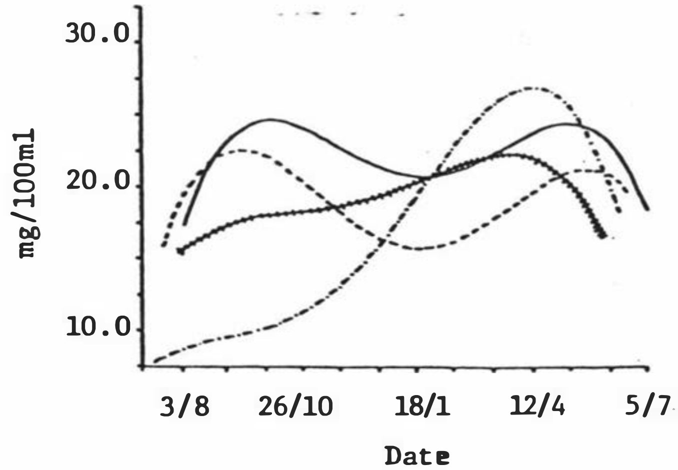

Figure V: 20

Awaroa herd & all 3 Massey herds
Urea nitrogen
Time in 4 week intervals
Simultaneous plot

Other than the general stability of these parameters there was little that warranted further comment in respect to the values for protein and albumin measured in this herd.

Urea Nitrogen

The mean plasma urea nitrogen level on the Awaroa property of 19.26 ± 2.44 mg/100ml indicated that the average level of protein intake was very satisfactory (Table V:1). When the shape of the curves for urea nitrogen plotted against season were compared however, (Fig. V:20), considerable differences between the Massey units and Awaroa could be seen. There was no clear peak during the spring period at Awaroa when grass growth would be expected to be high. Unit 3 similarly had no spring peak (Fig. IV:94), a feature considered to have been associated with under-feeding at a time when the demands of lactation were high (see p 186).

It is likely therefore that underfeeding during early lactation did take place in the Awaroa herd and that the relatively good body condition of the cattle at that time could have been the result of feeding management in the period prior to calving. The falling glucose levels after calving (Fig. V:25) as well as the fall in haematocrit during the 4-25 week period (Fig. V:1) add support to the conclusion that underfeeding did occur.

The curve for urea nitrogen against weeks in milk (Fig. V:21) was very similar to the curve for urea nitrogen against weeks from the start (Fig. V:19) once again illustrating the difficulties of identifying the causes of variation when seasonal changes, as well as changes in the stage of lactation, occur simultaneously.

Age had no significant influence on the level of serum urea nitrogen in the Awaroa herd (Table V:2).

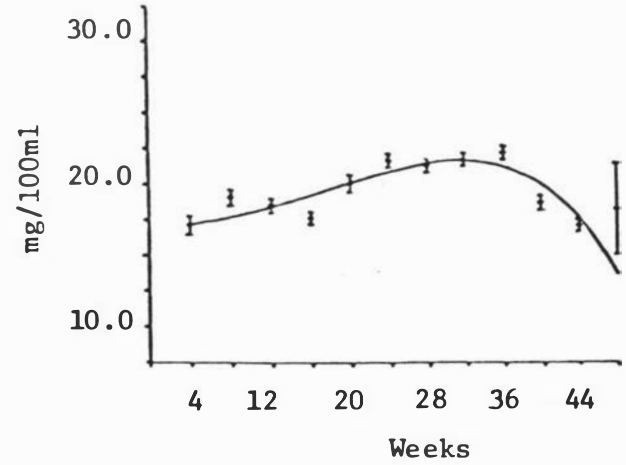

Figure V: 21

Awaroa herd R.P.D.
Urea nitrogen
Weeks in milk

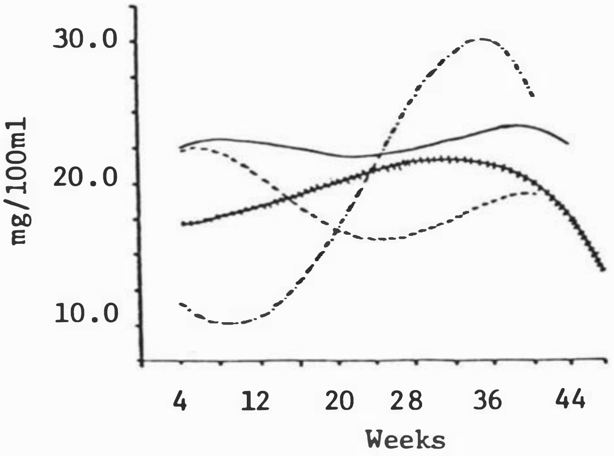

Figure V: 22

Awaroa herd & all 3 Massey herds
Urea nitrogen
Weeks in milk
Simultaneous plot

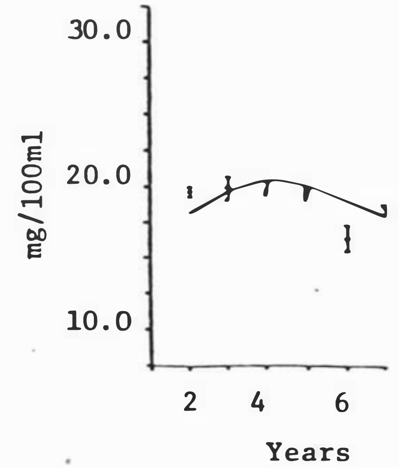

Figure V: 23

Awaroa herd R.P.D.
Urea nitrogen
Age

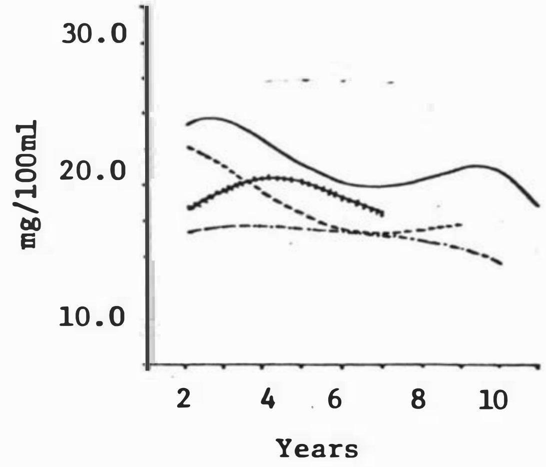

Figure V: 24

Awaroa herd & all 3 Massey herds
Urea nitrogen
Age
Simultaneous plot

Glucose

The Awaroa cattle had serum glucose levels that were both lower and more variable than those registered for the Massey units (Tables IV:1 and V:1). Why this should have been the case is not known since the mean values for urea nitrogen in the Awaroa herd (previous section) indicated that the nutritional level was satisfactory as did their body condition. A period during early lactation when underfeeding may have existed however (see urea nitrogen discussion) could prove an explanation for these glucose values. The fitted values for glucose against both season and weeks in milk (Figs. V:25 and V:27) were similar and appeared to follow the pattern of the two Massey seasonal dairying units (Units 2 and 3).

Age had no significant effect on glucose levels in the Awaroa herd (Table V:2).

Sodium and Potassium

The mean serum sodium level for the Awaroa herd was very similar to that for the U.K. (Tables IV:1 and V:1). This was to be expected once the initial problems associated with sodium estimations (see pp 203-4) had been largely overcome. However the variability of the result (s.d. of 6.12 mEq/l for the Awaroa herd compared with s.d. of 2.1 mEq/l for the U.K.) was high and there was no obvious explanation for this. In view of the importance of sodium in maintaining osmotic pressure such variability is unexpected.

The potassium level (4.91 ± 0.4 mEq/l was slightly below the level recorded for the U.K. (Tables IV:1 and V:1).

Serum sodium levels plotted against both season (Fig. V:31) and weeks in milk (Fig. V:33) showed marked differences from those for the Massey herds (Fig. V:32 and V:34). Some of these differences could have been associated with the analytical problems for sodium that were discussed earlier

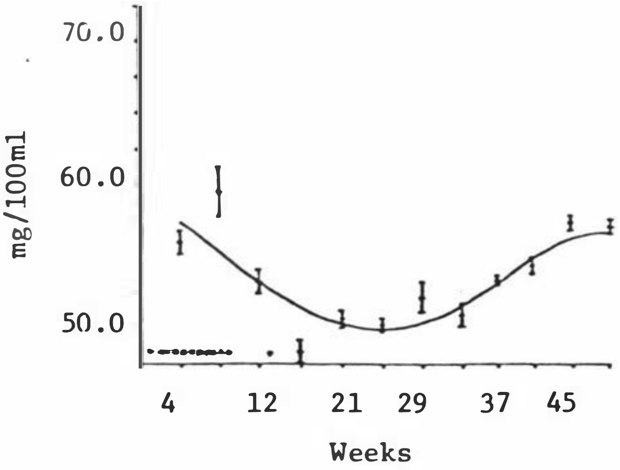

Figure V: 25

Awaroa herd R.P.D.
Glucose
Time in 4 week intervals(approx)

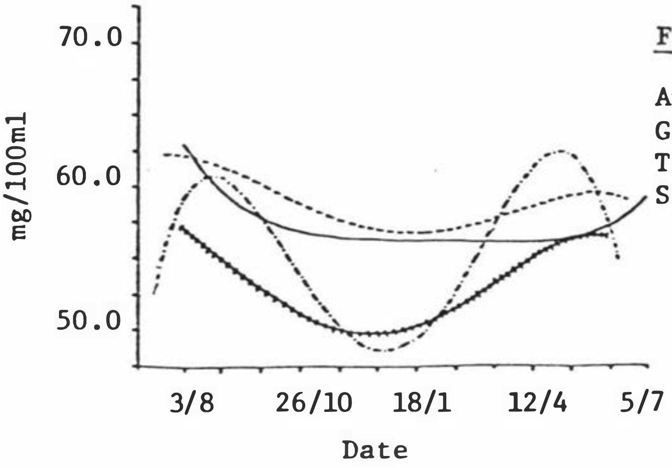

Figure V: 26

Awaroa herd & all 3 Massey herds
Glucose
Time in 4 week intervals
Simultaneous plot

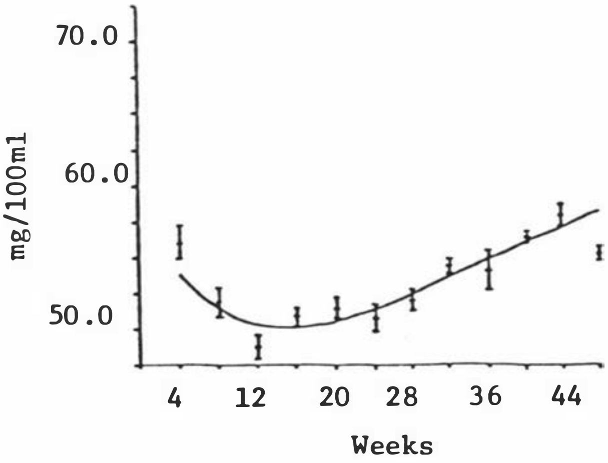

Figure V: 27

Awaroa herd R.P.D.
Glucose
Weeks in milk

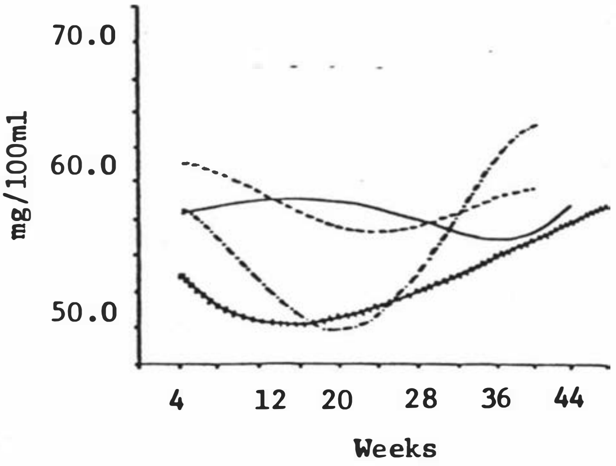

Figure V: 28

Awaroa herd & all 3 Massey herds
Glucose
Weeks in milk
Simultaneous plot

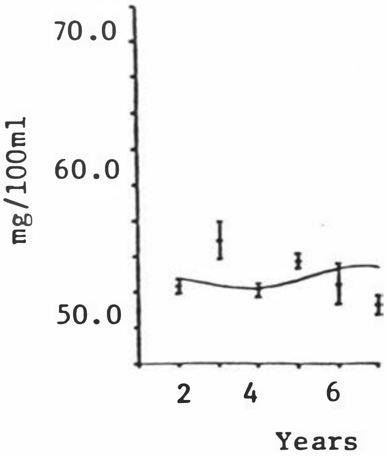

Figure V: 29

Awaroa herd R.P.D.
Glucose
Age

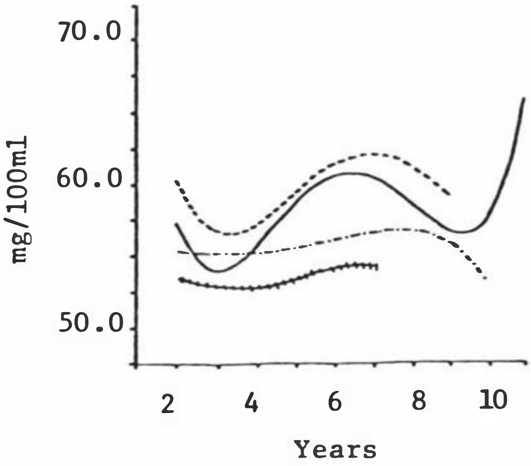

Figure V: 30

Awaroa herd & all 3 Massey herds
Glucose
Age
Simultaneous plot

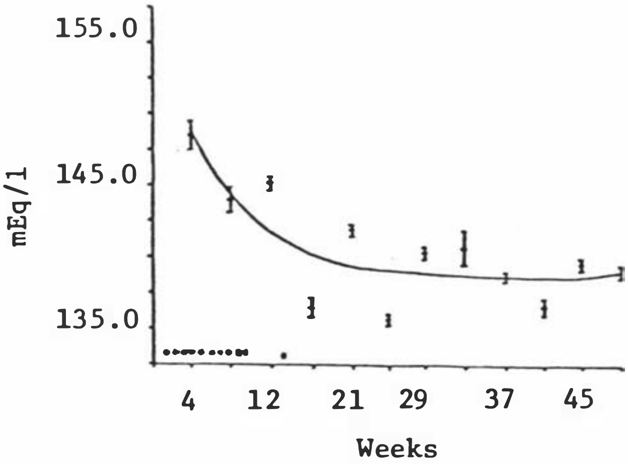

Figure V: 31

Awaroa herd R.P.D.
Sodium
Time in 4 week intervals

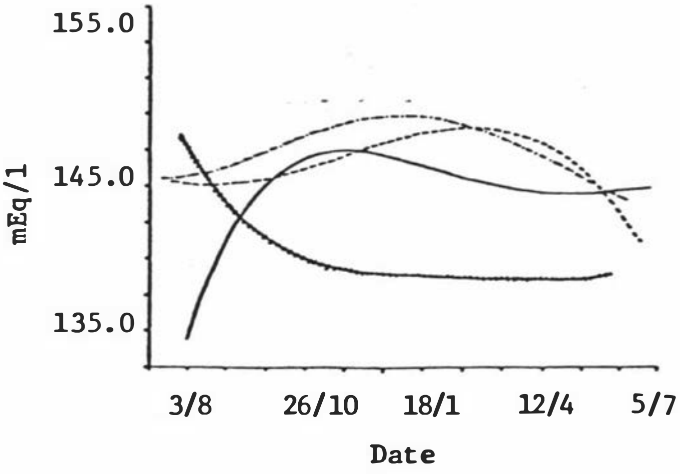

Figure V: 32

Awaroa herd & all 3 Massey herds
Sodium
Simultaneous plot by time

(pp 203-4). Both curves in the Awaroa herd followed a similar pattern although the means for sodium against weeks in milk fitted the curve with much more precision than did those for season.

Similar comments apply to the plots for potassium (Figs. V:37 and V:39). Visual appraisal of Fig. V:39 indicated an anomaly in that the means for serum potassium fell toward the end of lactation (as in Fig. V:37) whereas the graph itself showed a rise. This illustrates the deficiencies of polynomial plots, especially when there is a low order of explanation, as with levels of either sodium or potassium.

The movement in serum levels of either sodium or potassium seemed relatively small in the Awaroa herd irrespective of whether they were related to the time of year or to lactation. Because of the seasonal pattern of calving in the herd it was difficult to determine which of the two variables was having the greater effect; a similar amount of variation was explained by season and by lactation in each case (Table V:2).

Age effects in respect to either electrolyte were non significant (Table V:2).

Magnesium

The level of magnesium in the Awaroa herd was very similar to the level obtained in the U.K. suggesting that magnesium nutrition was satisfactory. Plotted against weeks from the start (Fig. V:45) and for weeks in milk (Fig. V:45) magnesium illustrated similar changes; it rose from a low point at the start to a peak in mid to late summer (January-February) and then declined to a low point again. This curve was consistent with the findings of other

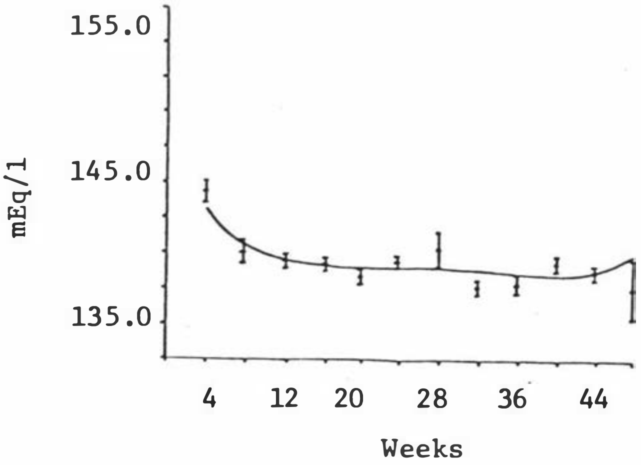

Figure V: 33

Awaroa herd R.P.D.
Sodium
Weeks in milk

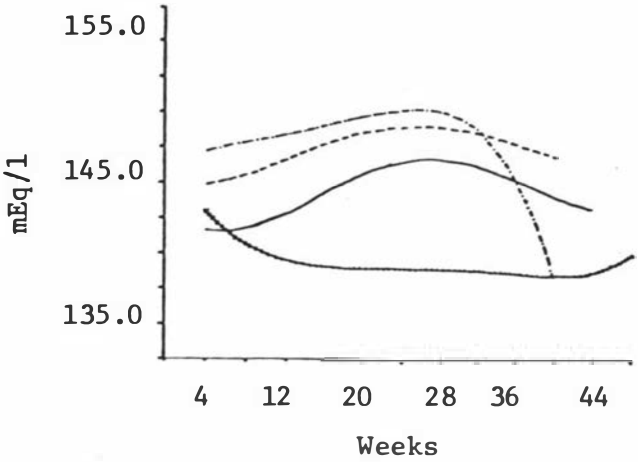

Figure V: 34

Awaroa herd & all 3 Massey herds
Sodium
Weeks in milk
Simultaneous plot

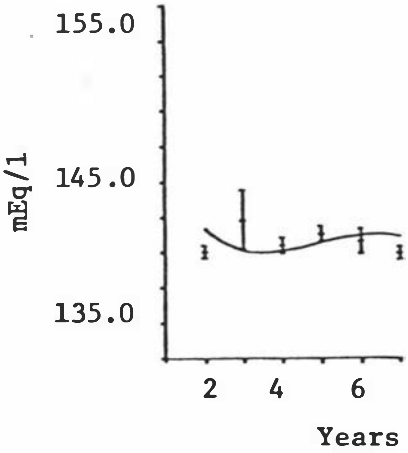

Figure V: 35

Awaroa herd R.P.D.
Sodium
Age

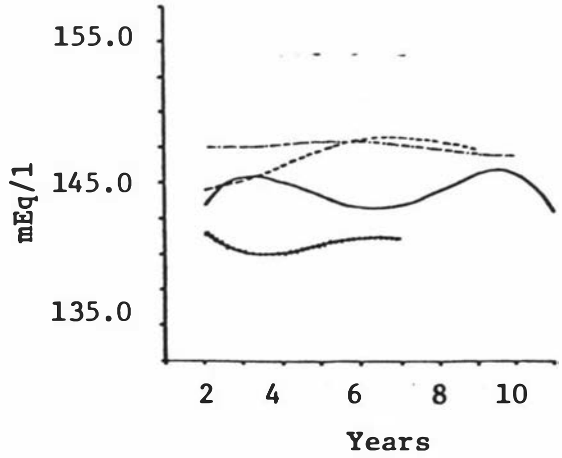

Figure V: 36

Awaroa herd & all 3 Massey herds
Sodium
Age
Simultaneous plot

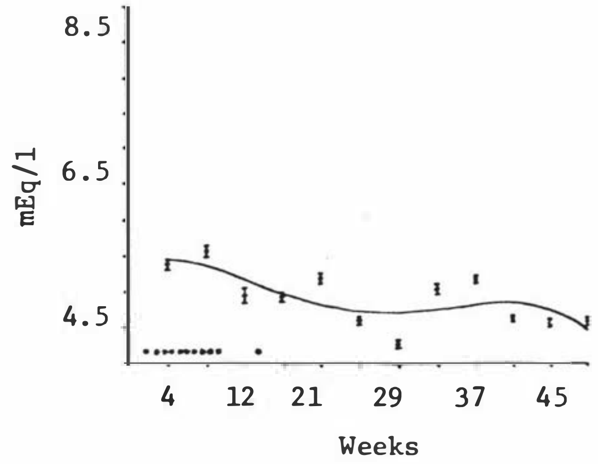

Figure V: 37

Awaroa herd R.P.D.
Potassium
Time in 4 week intervals(approx)

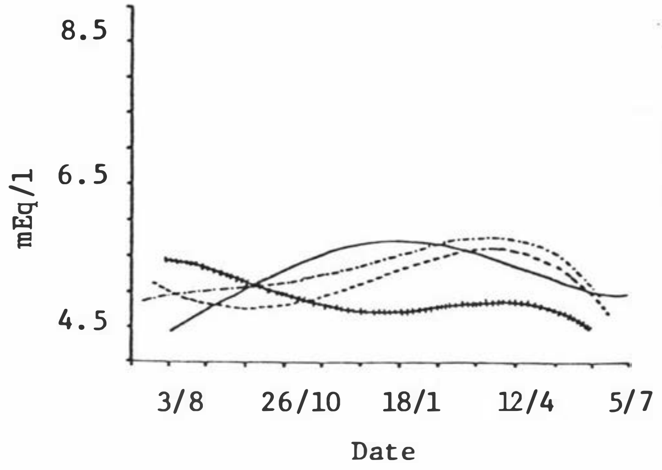

Figure V: 38

Awaroa herd & all 3 Massey herds
Potassium
Time in 4 week intervals
Simultaneous plot

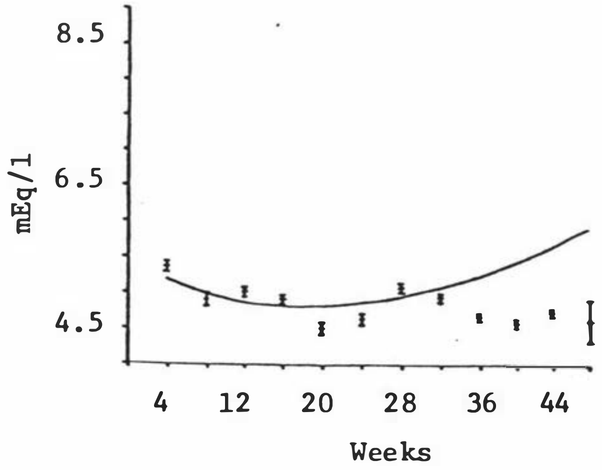

Figure V: 39

Awaroa herd R.P.D.
Potassium
Weeks in milk

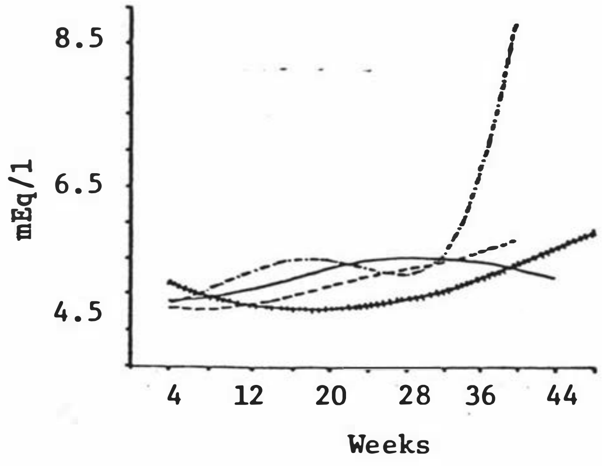

Figure V: 40

Awaroa herd & all 3 Massey herds
Potassium
Weeks in milk

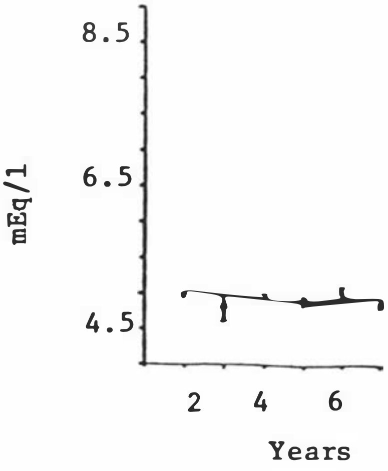

Figure V: 41

Awaroa herd R.P.D.
Potassium
Age

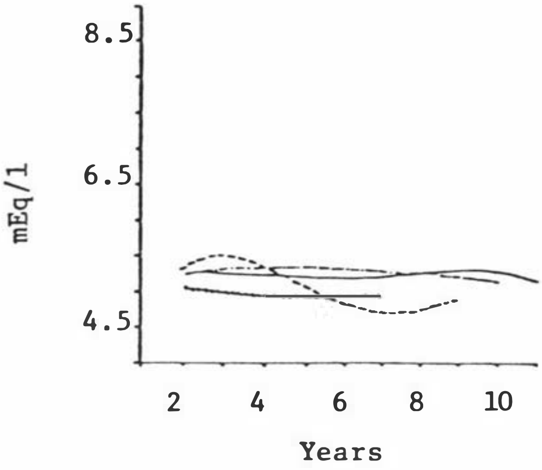

Figure V: 42

Awaroa herd & all 3 Massey herds
Potassium
Age
Simultaneous plot

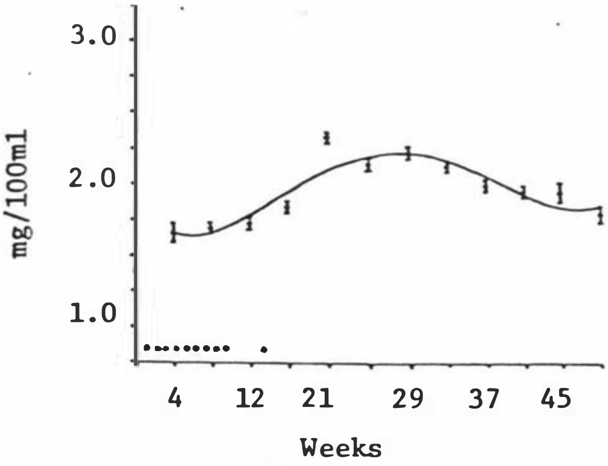

Figure V: 43

Awaroa herd R.P.D.
Magnesium
Time in 4 week intervals(approx)

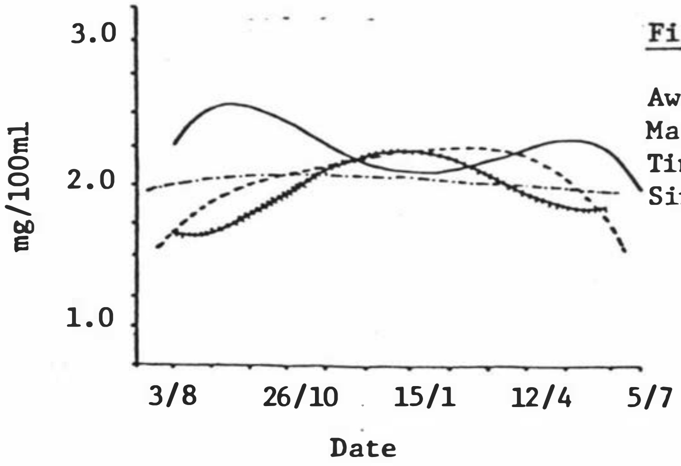

Figure V: 44

Awaroa herd & all 3 Massey herds
Magnesium
Time in 4 week intervals
Simultaneous plot

workers (Young *et al.*, 1979) where over the winter time the serum magnesium was at its lowest. The reasons advanced for this lowered serum magnesium level in winter have been associated with alterations in availability of the element in the diet - this in turn is associated with changing pasture composition. These changes were considered in the Review of Literature (pp. 74-90).

There was no consistent change in magnesium level in relation to age on the Awaroa unit (Fig. V:47).

Calcium

As discussed earlier (p. 143) problems were experienced with the calcium analyses. Material was therefore held in storage for long periods of time before the analyses were run for the Awaroa herd. Whether as a consequence of this, or for some other reason, the results for the calcium analyses for the Awaroa cattle were significantly lower than for cattle on the Massey units - so low in fact that many values obtained were incompatible with life. As there were no clinical problems with cattle yielding these low results the estimations were obviously not valid.

Repeats of these analyses were run with essentially the same result. One possible explanation was that the Auto-analyzer storage cups used for these samples absorbed the calcium either onto their surface or into the plastic thus giving erroneously low values. Unfortunately there was no opportunity to test this hypothesis. Since these results were not reliable they were not given further consideration. As a consequence the Awaroa and Massey means for serum calcium have not been entered in Table V:1. Figs. V:49-54 have been retained simply to illustrate the nature of the problem.

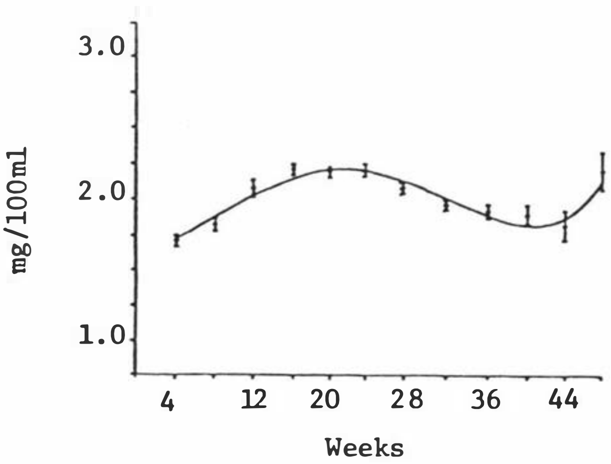

Figure V: 45

Awaroa herd R.P.D.
Magnesium
Weeks in milk

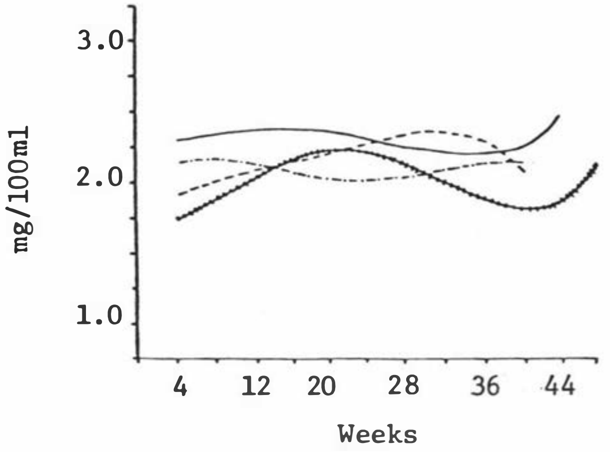

Figure V: 46

Awaroa herd & all 3 Massey herds
Magnesium
Weeks in milk
Simultaneous plot

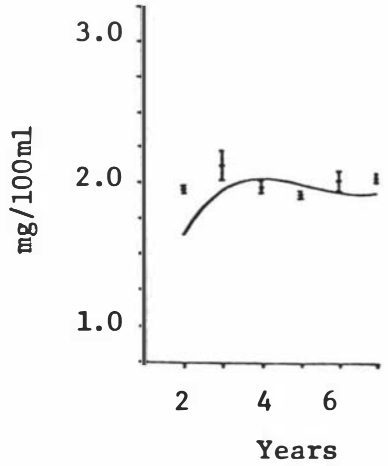

Figure V: 47

Awaroa herd R.P.D.
Magnesium
Age

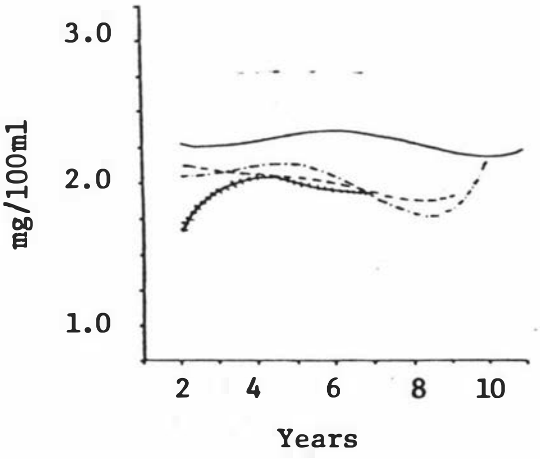

Figure V: 48

Awaroa herd & all 3 Massey herds
Magnesium
Age

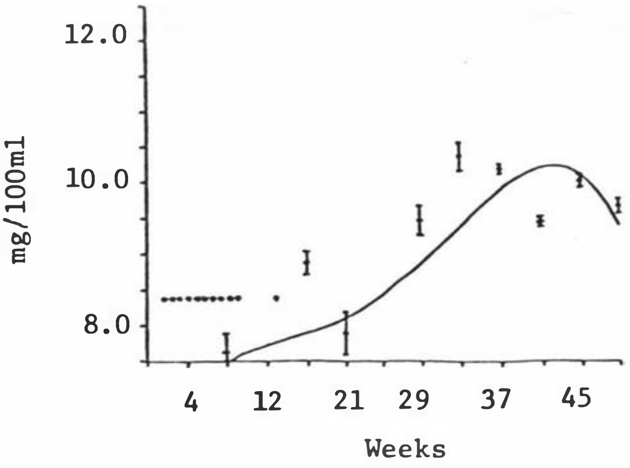

Figure V: 49

Awaroa herd R.P.D.
Calcium
Time in 4 week intervals(approx)

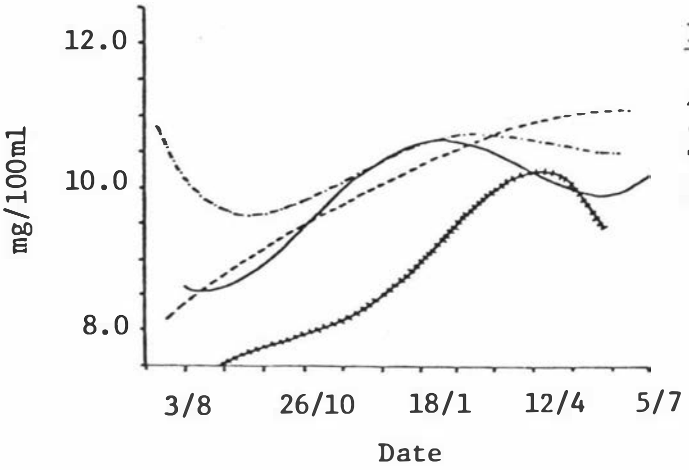

Figure V: 50

Awaroa herd & all 3 Massey herds
Calcium
Time in 4 week intervals
Simultaneous plot

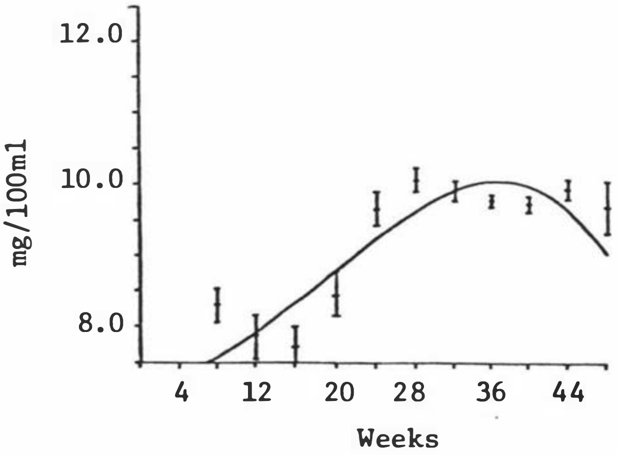

Figure V: 51

Awaroa herd R.P.D.
Calcium
Weeks in milk

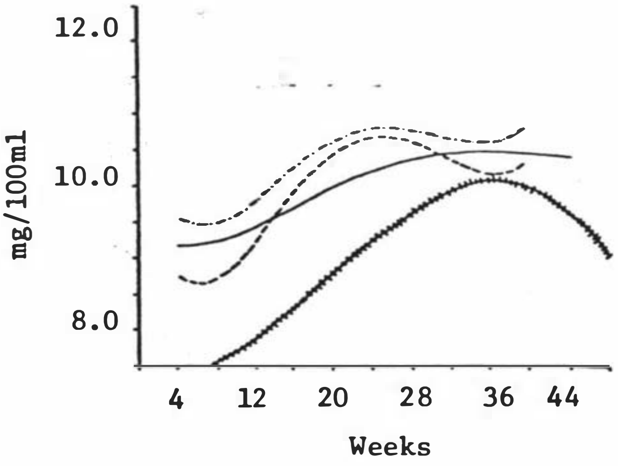

Figure V: 52

Awaroa herd & all 3 Massey herds
Calcium
Weeks in milk
Simultaneous plot

Inorganic Phosphate

The serum inorganic phosphate levels were the lowest of those recorded for the four herds investigated in New Zealand (Tables IV:1 and V:1). Nevertheless there was no clinical evidence of phosphate deficiency suggesting that these herds had serum phosphate levels still within the range of normality. The Awaroa property was flat, near the sea and a product of river and glacial alluvial deposits that required good drainage to prevent saturation of the soil with water. In spite of regular phosphate applications soil leaching of phosphate could reduce the amount available in both soil and pasture. Whether this provided the explanation for the low result or not has not been confirmed since plant and soil phosphate estimations were outside the scope of the project.

In all other respects the plots for phosphate against season, weeks in milk and age were essentially the same as those for the Massey units.

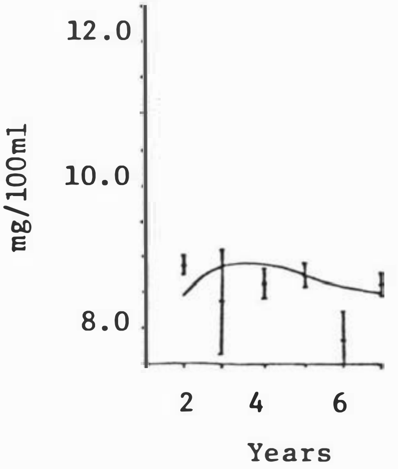

Figure V: 53

Awaroa herd R.P.D.
Calcium
Age

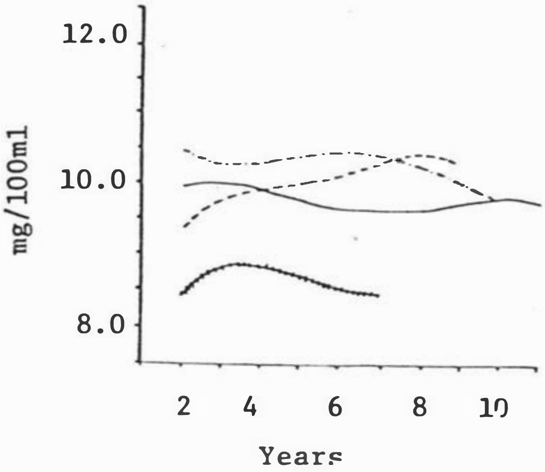

Figure V: 54

Awaroa herd & all 3 Massey herds
Calcium
Age
Simultaneous plot

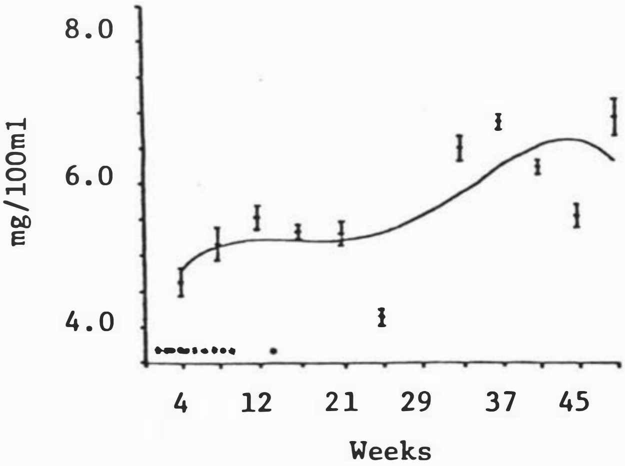

Figure V: 55

Awaroa herd R.P.D.
Inorganic phosphate
Time in 4 week intervals(approx)

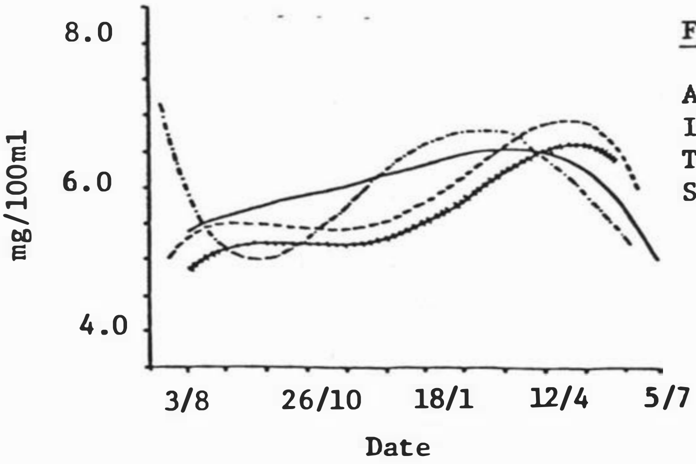

Figure V: 56

Awaroa herd & all 3 Massey herds
Inorganic phosphate
Time in 4 week intervals
Simultaneous plot

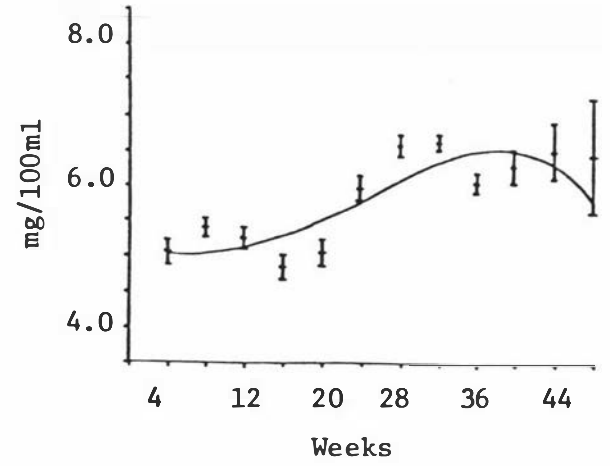

Figure V: 57

Awaroa herd & R.P.D.
Inorganic phosphate
Weeks in milk

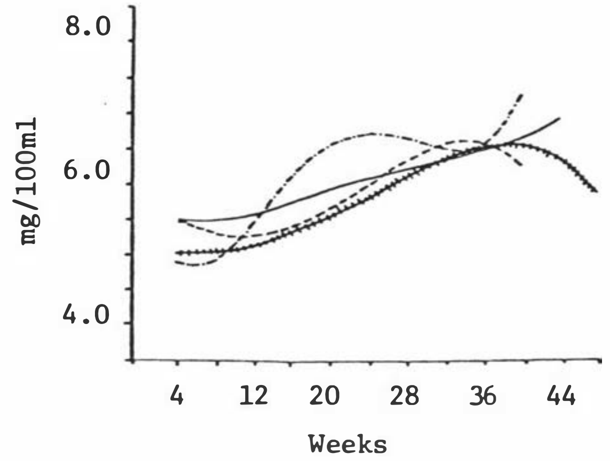

Figure V: 58

Awaroa herd & all 3 Massey herds
Inorganic phosphate
Weeks in milk
Simultaneous plot

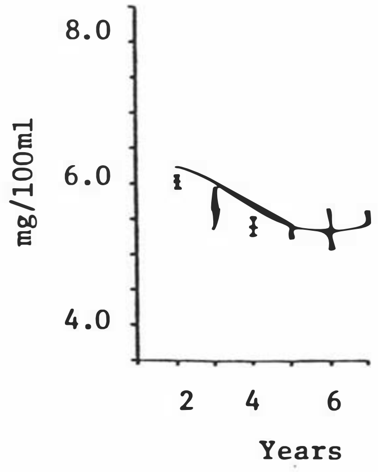

Figure V: 59

Awaroa herd R.P.D.
Inorganic phosphate
Age

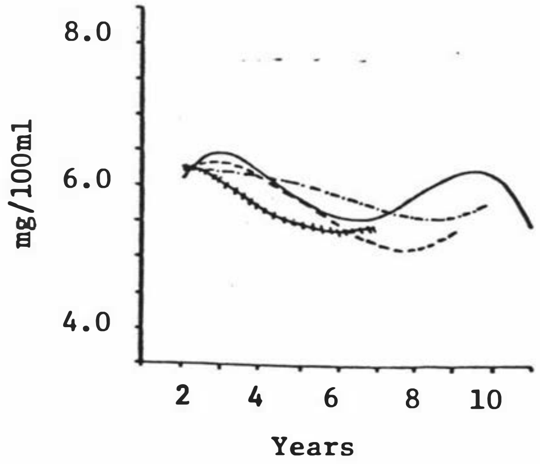

Figure V: 60

Awaroa herd & all 3 Massey herds
Inorganic phosphate
Age
Simultaneous plot

CHAPTER VI

RESULTS AND DISCUSSION (PART C)

As a result of losses due to death of one of the members of two twin pairs, a choice had to be made between analyzing data for either 7 twin pairs for 13 months or 5 twin pairs for 15 months. The first option was selected as it provided more information. A four way analysis of variance was carried out on the IBM1620 Mk II computer for each of the 11 parameters studied and the components of variation calculated for those variables which were significant. These results are shown in Tables VI:1-11. Table VI:12 summarises these components of variation in a single table allowing ready comparison between the parameters. Means for the eleven parameters, while not important to this part of the investigation, have been calculated and are listed in Appendix C (Table C:1).

The most striking feature of these analyses was that the month by month (seasonal) variation accounted for a substantial amount of the variability seen in all parameters. This was not unexpected in view of the many changing environmental factors that occur with changing seasons particularly in respect to the quantity and quality of food on offer (see earlier discussions) and the changing physiological states of the animals eating that food (lactation and pregnancy). Genetic influences and day to day variations yielded a lesser contribution to the variation but in some instances were important - these are commented on in respect to each parameter later in the discussion. Unfortunately much of the variability remains unaccounted for (as residual variance), particularly in respect to some of the ions such as sodium, potassium, calcium and inorganic phosphate, and an understanding of this requires a great deal more work in respect to both precision in analytical method as well as a better appreciation of the many factors governing blood levels at any one point in time. Some of these factors were studied in the next part of the thesis.

Haematocrit and Haemoglobin

Both the haematocrit and haemoglobin levels were influenced to a considerable extent by season (month to month variation) confirming the findings already reported in the first two parts of this thesis. Possible reasons for this were discussed on pp 148-158).

A second characteristic of these parameters that was noteworthy was the manner in which each twin pair responded over the total sampling period with the within pair variation being very low compared to that between pairs. This suggests a considerable degree of genetic control (see Review of Literature), particularly in respect to the haematocrit (Table VI:12).

That some twin pairs reacted differently from others to the changes that were occurring in the environment each month (see interaction between months and pairs for the haematocrit values) is not unexpected where a strong genetic component is present. These three sources of variation (months, pairs and months by pairs) together accounted for approximately 95% of the variance for both parameters.

Total Protein and Albumin

Seasonal factors, probably associated with diet, were major determinants of the total protein and albumin levels. The effect on albumin was particularly marked accounting for over 80% of the variability observed with this parameter (Table VI:12). Genetic control of albumin was of minor importance but this was not the case with total protein. These results suggest that globulin, which was not measured directly in this project, responds to a wider and far different range of influences than does serum albumin with the result that albumin is a more sensitive indicator of protein nutrition than serum total protein. Serum urea nitrogen on the other hand, which also appears particularly sensitive to seasonal and other influences, responds not only to protein levels in the diet but also to non-protein nitrogen sources which lead to the

TABLE VI:1

ANALYSIS OF VARIANCE: HAEMATOCRIT

SOURCE OF VARIATION	DEGREES OF FREEDOM	MEAN SQUARE	VARIANCE COMPONENT	
Months	12	105.338	2.484	(20.3)*
Pairs	6	495.518	6.337	(51.9)
Months x pairs	72	11.501	1.741	(14.3)
Days(months)†	26	7.393	0.023	(0.2)
Animals(pairs)§	7	28.083	0.099	(0.8)
Months x animals(pairs)	84	10.889	0.468	(3.8)
Pairs x days(months)	156	1.271¶	-	-
Residual**	182	1.058	1.058	(8.7)
Total	545		12.210	(100.0)

* Component as a percentage of the total variance

† Nested effect of days within months

§ Nested effect of animals within pairs

¶ Not significant ($p > 0.05$)

**Interaction of days within months with animals within pairs

TABLE VI:2

ANALYSIS OF VARIANCE: HAEMOGLOBIN

SOURCE OF VARIATION	DEGREES OF FREEDOM	MEAN SQUARE	VARIANCE COMPONENT	
Months	12	35.5641	0.8432	(41.8)*
Pairs	6	63.1344	0.8061	(39.9)
Months x pairs	72	1.1014	0.1589	(7.9)
Days(months)†	26	1.6027	0.0080	(0.4)
Animals(pairs)§	7	4.1772	0.0147	(0.7)
Months x animals(pairs)	84	0.9010	0.0358	(1.8)
Pairs x days(months)	156	0.2550	0.0041	(0.2)
Residual¶	182	0.1482	0.1482	(7.3)
Total	545		2.0190	(100.0)

* Component as a percentage of the total variance

† Nested effect of days within months

§ Nested effect of animals within pairs

¶ Interaction of days within months with animals within pairs

TABLE VI:3

ANALYSIS OF VARIANCE: TOTAL PROTEIN

SOURCE OF VARIATION	DEGREES OF FREEDOM	MEAN SQUARE	VARIANCE COMPONENT	
Months	12	15.8152	0.3744	(62.9)*
Pairs	6	6.0723	0.0767	(12.9)
Months x pairs	72	0.2907	0.0333	(5.6)
Days(months)†	26	1.5658	0.0081	(1.4)
Animals(pairs)§	7	0.6301	0.0020	(0.3)
Months x animals(pairs)	84	0.2409	0.0071	(1.2)
Pairs x days(months)	156	0.1763	0.0033	(0.6)
Residual¶	182	0.0910	0.0910	(15.3)
Total	545		0.5959	(100.0)

* Component as a percentage of the total variance

† Nested effect of days within months

§ Nested effect of animals within pairs

¶ Interaction of days within months with animals within pairs

TABLE VI:4

ANALYSIS OF VARIANCE: ALBUMIN

SOURCE OF VARIATION	DEGREES OF FREEDOM	MEAN SQUARE	VARIANCE COMPONENT	
Months	12	22.9959	0.5463	(84.1)*
Pairs	6	0.4222	0.0046	(0.7)
Months x pairs	72	0.2542	0.0338	(5.2)
Days(months)†	26	1.2564	0.0066	(1.0)
Animals(pairs)§	7	0.3868	0.0012	(0.2)
Months x animals(pairs)	84	0.1641	0.0054	(0.8)
Pairs x days(months)	156	0.0620¶	-	-
Residual**	182	0.0513	0.0513	(7.9)
Total	545		0.6492	(100.0)

* Component as a percentage of the total variance

† Nested effect of days within months

§ Nested effect of animals within pairs

¶ Not significant ($p > 0.05$)

**Interaction of days within months with animals within pairs

production of rumen ammonia. This limits the usefulness of serum urea nitrogen for monitoring the sufficiency of protein in the diet.

Day to day variation plays a lesser but still significant role in respect to serum total protein and albumin values; how or why such rapid changes occur is not yet understood.

Urea Nitrogen

Seasonal effects exerted a moderate influence on urea nitrogen concentrations, probably reflecting seasonal changes in the protein content of the diet as discussed earlier.

A genetic effect was also indicated by the contribution of twin pairs and the months by twin pairs interaction to the total variance (Table VI:12). Whether this was manifested by differences in eating behaviour, e.g. aggression, or whether it was associated with other innate metabolic differences between pairs is a matter for speculation. Taking both the effect of pairs and pairs by months, the gross genetic influence amounted to 50% of the variance: less than the haematocrit but equivalent to that for haemoglobin.

One other important factor accounting for the variation in this parameter was the interaction between months and animals within pairs. Clearly blood urea nitrogen levels are sensitive to a wide variety of influences and it is therefore not surprising that the mean serum urea nitrogen levels reported in the earlier part of this project were associated with high standard deviations (see Table IV:1).

Glucose

The major contribution to the variation seen in glucose levels during this part of the investigation was that associated with season (Table VI:12). While it is tempting to ascribe this variation to changes in the energy composition of the diet it

TABLE VI:5

ANALYSIS OF VARIANCE: UREA NITROGEN

SOURCE OF VARIATION	DEGREES OF FREEDOM	MEAN SQUARE	VARIANCE COMPONENT	
Months	12	487.277	11.535	(33.2)*
Pairs	6	414.858	5.297	(15.2)
Months x pairs	72	75.753	12.159	(35.0)
Days(months)†	26	116.499	0.625	(1.8)
Animals(pairs)§	7	70.407	0.248	(0.7)
Months x animals(pairs)	84	43.553	1.941	(5.6)
Pairs x days(months)	156	6.264	0.133	(0.4)
Residual**	182	2.802	2.802	(8.1)
Total	545		34.740	(100.0)

* Component as a percentage of the total variation

† Nested effect of days within months

§ Nested effect of animals within pairs

**Interaction of days within months with animals within pairs

is unlikely that this was the sole cause of the variation as no constant relationship has been found between blood glucose and energy intake even when the energy intake was inadequate (Parker and Blowey, 1976). It is probable that other exogenous and endogenous factors that affect energy requirements such as weather, lactation and pregnancy also influenced resting blood glucose levels so that at any one time the level of glucose recorded in the blood will be the product of a wide range of interacting influences.

Genetic influences on glucose were smaller than on urea nitrogen and were equivalent to that in the case of total protein since pairs and pairs by months accounted for 21% of the total variation.

Sodium and Potassium

Serum levels of sodium and potassium varied on a long term seasonal basis and to a much lesser extent on a short term (day to day) basis - see Table VI:12. A changing content of these elements in the diet together with the demands of lactation provide the most likely explanation for the month by month variation observed. The short term variation was an individual animal response probably associated with the amount and type of feed consumed immediately prior to the time of sampling. Salivary flow for example varies according to the nature of the diet and saliva is rich in these two ions (see Literature Review). Some of these short term effects were examined in Part D of this study.

Sodium but not potassium was affected to a minimal degree by genetic influences.

TABLE VI:6

ANALYSIS OF VARIANCE: GLUCOSE

SOURCE OF VARIATION	DEGREES OF FREEDOM	MEAN SQUARE	VARIANCE COMPONENT	
Months	12	2039.63	48.19	(56.7)*
Pairs	6	353.33	4.07	(4.8)
Months x pairs	72	99.04	13.88	(16.3)
Days(months)†	26	135.63	0.66	(0.8)
Animals(pairs)§	7	70.30	0.20	(0.2)
Months x animals(pairs)	84	48.47	1.56	(1.8)
Pairs x days(months)	156	34.59	0.72	(0.9)
Residual¶	182	15.78	15.78	(18.6)
Total	545		85.06	(100.0)

* Component as a percentage of the total variance

† Nested effect of days within months

§ Nested effect of animals within pairs

¶ Interaction of days within months with animals within pairs

TABLE VI:7

ANALYSIS OF VARIANCE: SODIUM

SOURCE OF VARIATION	DEGREES OF FREEDOM	MEAN SQUARE	VARIANCE COMPONENT	
Months	12	267.417	6.305	(60.6)*
Pairs	6	25.833	0.266	(2.6)
Months x pairs	72	6.391	0.629	(6.0)
Days(months)†	26	64.654	0.341	(3.3)
Animals(pairs)§	7	9.857	0.027	(0.3)
Months x animals(pairs)	84	5.405	0.133	(1.3)
Pairs x days(months)	156	5.096	0.095	(0.9)
Residual¶	182	2.615	2.615	(25.1)
Total	545		10.411	(100.0)

* Component as a percentage of the total variance

† Nested effect of days within months

§ Nested effect of animals within pairs

¶ Interaction of days within months with animals within pairs

TABLE VI:8

ANALYSIS OF VARIANCE: POTASSIUM

SOURCE OF VARIATION	DEGREES OF FREEDOM	MEAN SQUARE	VARIANCE COMPONENT	
Months	12	8.5061	0.2000	(46.8)*
Pairs	6	4.6912	0.0583	(13.6)
Months x pairs	72	0.3938	0.0482	(11.3)
Days(months)†	26	2.9154	0.0154	(3.6)
Animals(pairs)§	7	0.0924¶	-	-
Months x animals(pairs)	84	0.1106¶	-	-
Pairs x days(months)	156	0.1432	0.0015	(0.4)
Residual**	182	0.1043	0.1043	(24.4)
Total	545		0.4277	(100.0)

* Component as a percentage of the total variance

† Nested effect of days within months

§ Nested effect of animals within pairs

¶ Not significant ($p > 0.05$)

**Interaction of days within months with animals within pairs

Magnesium

The observation that blood magnesium levels were influenced by season agrees with the findings in Part B of the project (Table V:2) but not those in Part A (Table IV:2). If this was associated with dietary influences, as seems likely, it is not surprising that between year differences occurred between herds sampled at different locations and in different seasons.

In view of the apparent sensitivity of serum magnesium levels to intake, day to day variations were anticipated but did not arise.

Calcium

Important seasonal effects on serum calcium levels were observed, a surprising finding in view of the complex homeostatic mechanisms operating to maintain serum calcium stability (see Literature Review). In Part A of the project a significant amount of variation was similarly ascribed to seasonal effects on Units 1 and 2. There would appear to be a demand, perhaps associated with the heavy demand on calcium in early lactation, which cannot be adequately met from either exogenous sources in the diet or by endogenous bone supplies, that results in lower serum calcium levels in the early postpartum period in some dairy cattle.

Genetic effects were observed with 13% of the total variance accounted for by differences between pairs. There was in addition a smaller proportion of total variance associated with a significant pairs x month interaction.

A major problem with calcium concerned the large amount of residual variation recorded (Table VI: 12), an observation which agrees with the relatively high experimental error noted for this analysis by Rowlands and Pocock (1971).

TABLE VI:9

ANALYSIS OF VARIANCE: MAGNESIUM

SOURCE OF VARIATION	DEGREES OF FREEDOM	MEAN SQUARE	VARIANCE COMPONENT	
Months	12	8.1407	0.1925	(68.8)*
Pairs	6	0.8295	0.0097	(3.5)
Months x pairs	72	0.1799	0.0207	(7.4)
Days(months)†	26	0.1661	0.0006	(0.2)
Animals(pairs)§	7	0.2649	0.0008	(0.3)
Months x animals(pairs)	84	0.0694¶	-	-
Pairs x days(months)	156	0.0709¶	-	-
Residual**	182	0.0557	0.0557	(19.9)
Total	545		0.2800	(100.0)

* Component as a percentage of the total variance

† Nested effect of days within months

§ Nested effect of animals within pairs

¶ Not significant ($p > 0.05$)

**Interaction of days within months with animals within pairs

TABLE VI:10

ANALYSIS OF VARIANCE: CALCIUM

SOURCE OF VARIATION	DEGREES OF FREEDOM	MEAN SQUARE	VARIANCE COMPONENT	
Months	12	13.6814	0.3205	(46.5)*
Pairs	6	7.3132	0.0897	(13.1)
Months x pairs	72	0.4110	0.0320	(4.7)
Days(months)†	26	1.6278	0.0077	(1.1)
Animals(pairs)§	7	1.7801	0.0058	(0.9)
Months x animals(pairs)	84	0.3374	0.0056	(0.8)
Pairs x days(months)	156	0.3134	0.0037	(0.5)
Residual¶	182	0.2189	0.2189	(32.0)
Total	545		0.6838	(100.0)

* Component as a percentage of the total variance

† Nested effect of days within months

§ Nested effect of animals within pairs

¶ Interaction of days within months with animals within pairs

Inorganic Phosphate

The results for serum inorganic phosphate levels indicated that dietary and other changes that might be expected to be associated with season had relatively little influence on this parameter. Significant day to day variation did occur and significant interactions were recorded between both months and twin pairs and months by animals within twin pairs. The biological importance of these effects is not clear.

The possibility that variations in the haemoconcentration/ dilution were responsible for some of the variation in blood levels of other parameters was investigated by calculating the correlation between haematocrit and haemoglobin and the other parameters. The results are presented in Appendix C Tables C:3-5 and showed no consistent pattern of relationship for any parameter.

TABLE VI:11

ANALYSIS OF VARIANCE: INORGANIC PHOSPHATE

SOURCE OF VARIATION	DEGREES OF FREEDOM	MEAN SQUARE	VARIANCE COMPONENT	
Months	12	15.5471	0.3605	(22.1)*
Pairs	6	11.8913	0.1451	(8.9)
Months x pairs	72	3.6730	0.5443	(33.4)
Days(months)†	26	8.2158	0.0429	(2.6)
Animals(pairs)§	7	4.5582	0.0152	(0.9)
Months x animals(pairs)	84	2.6839	0.1084	(6.7)
Pairs x days(months)	156	0.5744	0.0064	(0.4)
Residual¶	182	0.4069	0.4069	(25.0)
Total	545		1.6297	(100.0)

* Component as a percentage of the total variance

† Nested effect of days within months

§ Nested effect of animals within pairs

¶ Interaction of days within months with animals within pairs

TABLE VI:12

SUMMARY OF THE COMPONENTS OF VARIANCE FOR THE ELEVEN PARAMETERS:

EXPRESSED AS PERCENTAGES OF THE TOTAL VARIANCE FOR EACH PARAMETER

SOURCE OF VARIATION	HAEMATOCRIT	HAEMOGLOBIN	TOTAL PROTEIN	ALBUMIN	UREA NITROGEN	GLUCOSE	SODIUM	POTASSIUM	MAGNESIUM	CALCIUM	INORGANIC PHOSPHATE
Months	23.5	41.8	62.9	84.1	33.2	56.7	60.6	46.8	68.8	46.8	22.1
Pairs	51.9	39.9	12.9	0.7	15.2	4.8	2.6	13.6	3.5	13.1	8.9
Months x pairs	14.3	7.9	5.6	5.2	35.0	16.3	6.0	11.3	7.4	4.7	33.4
Days(months)	0.2	0.4	1.4	1.0	1.8	0.8	3.3	3.6	0.2	1.1	2.6
Animals(pairs)	0.8	0.7	0.3	0.2	0.7	0.2	0.3	-	0.3	0.9	0.9
Months x animals(pairs)	3.8	1.8	1.2	0.8	5.6	1.8	1.3	-	-	0.8	6.7
Pairs x days(months)	-	0.2	0.6	-	0.4	0.9	0.9	0.4	-	0.5	0.4
Residual	8.7	7.3	15.3	7.9	8.1	18.6	25.1	24.4	19.9	32.0	25.0

CHAPTER VII

RESULTS AND DISCUSSION :(PART D)

Ten of the twelve cattle that were used in this trial died after its completion. The first died 24 days after the termination of the sampling, and the last died 8 months later. At necropsy, severe lung infarcts and abscesses, endocarditis and phlebitis and abscessation of the jugular vein were seen in all cases. One animal showed systemic signs by day 10 of the sampling period and another showed signs of jugular abscessation by day 11. Similar signs were not observed until 20 days after the termination of the trial in the other animals and the animal which died first was the one which had shown clinical illness during the trial and had apparently responded to antibiotic therapy. No significant changes were noted in the haematocrit or other blood parameters which could indicate illness. Although two animals showed some clinical signs possibly affecting the results for the second of the six day cycles, these occurred towards the end of the trial and it has been assumed that the data from the first of the six day cycles would be affected to a minimal degree. The fact that no other animals showed signs for a further three weeks lends support to this assumption.

The cause of the problem was the indwelling catheters, a reaction which has also been recorded by Stober and Grunder (1979). The catheter causes trauma to the vein wall resulting in cauliflower-like growths due to endophlebitis. These subsequently became infected releasing material into the bloodstream and producing the endocarditis, and lung infarcts and abscesses noted on necropsy. If severe enough the inflammation closed the lumen of the vein resulting in collapse and abscessation.

Tables detailing the analyses of variance for the effects of amount of feed consumed, time since feeding, time since milking and time of day on each of the 11 parameters studied in Part D can be found in Appendix D. Table VII:1 shows the

TABLE VII:1 : CORRELATIONS BETWEEN THE INDEPENDENT VARIABLES

	x_1	x_2	x_2^2	x_2^3	x_2^4	x_3	x_3^2	x_3^3	x_3^4	x_4	x_4^2	x_4^3
x_2	.097											
x_2^2	.060	.965										
x_2^3	.043	.911	.986									
x_2^4	.033	.860	.958	.992								
x_3	-.076	-.024	-.016	-.013	-.010							
x_3^2	-.046	-.027	-.021	-.021	-.021	.859						
x_3^3	.002	-.004	-.005	-.010	-.013	.522	.873					
x_3^4	.023	.011	-.005	-.001	-.005	.346	.751	.977				
x_4	.262	.100	.068	.050	.038	-.006	-.050	-.001	.026			
x_4^2	.270	.082	.054	.039	.028	-.046	-.031	.011	.034	.976		
x_4^3	.262	.071	.046	.032	.021	-.033	-.019	.018	.038	.931	.987	
x_4^4	.248	.064	.041	.028	.018	-.026	-.012	.022	-.039	.885	.962	.993

x_1 Amount of feed consumed (Linear coefficient only)

x_2 x_2^2 x_2^3 x_2^4 Time since start of feeding (Linear to Quartic coefficients)

x_3 x_3^2 x_3^3 x_3^4 Time since start of milking (Linear to Quartic coefficients)

x_4 x_4^2 x_4^3 x_4^4 Time of day (Linear to Quartic coefficients) correlations between independant variables and these indicate that, apart from the expected high correlation between powers of the same variable, the only variables to show significant correlations were time of day and its powers with the amount of feed consumed. The amount of variation explained by each independent variable, is summarised in Table VII:2.

Curves representing the effects of variables having major influence on the parameters are shown in Figs. VII:1-8. The findings for each parameter are considered below with attention being directed only to those variables having some significant effect on the parameter. Only a small proportion of the total variation observed could be accounted for by the variables examined - less than 20% for all the parameters except haemoglobin, calcium and inorganic phosphate where 22.9%, 25.3% and 26.3% were accounted for by the sum of the sources of variation.

Haematocrit and Haemoglobin

Amount of food consumed at each offering had a significant negative effect on both parameters. This effect was essentially linear and accounted for 13.6% and 12.2% of the 'within animal and day' variance of haematocrit and haemoglobin. Time since food was offered also had an overall negative effect accounting for 8.6% and 17.1% of the variance for haematocrit and haemoglobin. In both cases the effect of this variable was best described by a polynomial to either the third or fourth power (see Fig. VII:1 & 2). The effect of these variables related to feed consumption on the two parameters appears likely to have been brought about by changes in fluid balance. Losses of fluid into the saliva associated with feeding appear to have been over-compensated by water consumed; a consequence of the dry food offered.

Time of day and time since milking were without effect on haematocrit and had only a minor influence on haemoglobin,

TABLE VII:2: THE EXTENT OF VARIATION IN BLOOD MEASUREMENTS ASSOCIATED WITH AMOUNT OF FOOD EATEN, TIME SINCE FEEDING, TIME SINCE MILKING AND TIME OF DAY.

	Amount of feed eaten	Time since feeding	Time since milking	Time of day
Haematocrit	13.6* (1)†	8.6 (3)	0.8 (4)	0.6 (4)
Haemoglobin	12.2 (1)	17.1 (4)	3.6 (4)	2.2 (1)
Total Serum Protein	10.2 (1)	0.0	0.0	0.0
Serum Albumin	9.9 (1)	1.1 (3)	0.7 (2)	0.2 (3)
Urea Nitrogen	0.0§	2.2 (3)	0.4 (3)	0.7 (4)
Glucose	0.5 (1)	4.2 (3)	0.5 (3)	0.0
Sodium	0.07 (1)	1.0 (3)	1.6 (3)	5.9 (1)
Potassium	1.1 (1)	3.0 (3)	0.4 (2)	2.7 (3)
Magnesium	1.9 (1)	4.9 (4)	0.1 (2)	0.0
Calcium	19.5 (1)	6.8 (4)	1.8 (4)	16.7 (3)
Inorganic Phosphate	0.0	13.6 (2)	2.3 (4)	10.4 (3)

§ No significant regression.

* Percentage of 'within animal and day' variance accounted for by the independent variable (= square of the multiple correlation coefficient)

† Power of polynomial equation which gave the 'best fit': (1) linear equation; (2) equation with linear and quadratic coefficients; (3) equation with linear, quadratic and cubic coefficients; (4) equation with linear, quadratic , cubic and quartic coefficients.

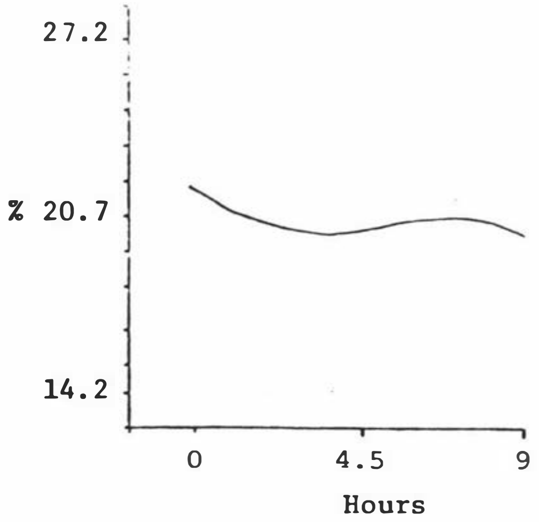

Figure VII:1

Haematocrit
Time since feeding

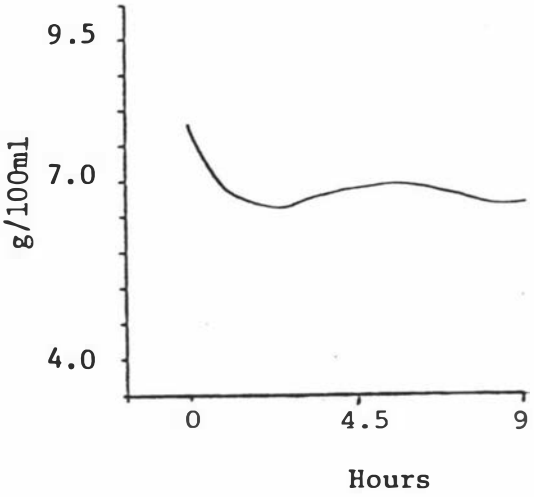

Figure VII:2

Haemoglobin
Time since feeding

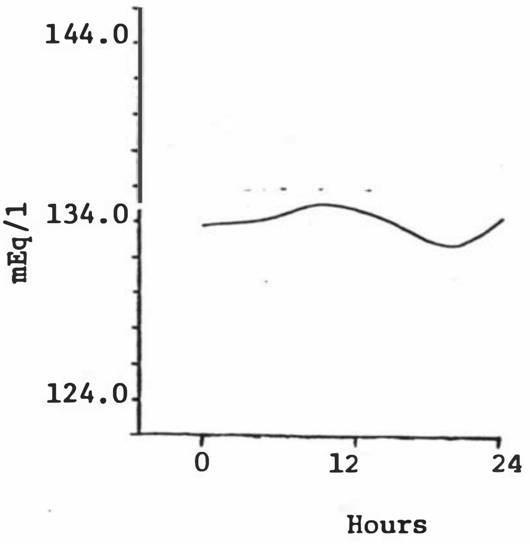

Figure VII:3

Sodium
Time of day

accounting in each case for less than 4% of the within animal and day variance.

Serum Total Protein and Albumin

Amount of food consumed at each offering had a significant positive linear effect accounting for approximately 10% of the within animal and day variance of both parameters. While the effect of time since feeding, time of day and time since milking were significant in the case of albumin in no case was the proportion of variation accounted for more than about 1%.

Urea Nitrogen

Amount of feed eaten had no significant effect on urea nitrogen although there was a significant non-linear effect of time since food was offered. This influence accounted for 2.2% of the within animal and day variance. The effects of time of day and time since milking were even smaller.

Glucose

Amount of food consumed had a significant positive linear effect which accounted for less than 1% of the variance. Time since feeding fitted as a polynomial to the third power accounted for 4% of the variance. Time since milking had even less effect and time of day was without effect on glucose.

Sodium

Amount of food consumed had a significant negative linear effect accounting for less than 0.1% of the variance of sodium level. Time since food was offered and time since milking when fitted as polynomials of the fourth or third power accounted for 1.0% and 1.6% of the variance. Time of day as a polynomial of the fourth power accounted for approximately 6% of the within animals - within days variance (Fig. VII:3). The sodium curve appears to show two peaks about midday and about midnight with troughs between. The cause of this minor diurnal variation is not known.

Potassium

Amount of food consumed had a significant negative effect on potassium of a greater magnitude than that seen with sodium but still accounting for only approximately 1% of the variance. The effect of time of day was less, and that of time since feeding greater than observed for sodium and both variables accounted for approximately 3% of the variance of potassium within animals and days. Time since milking accounted for less than 1% of the variance of potassium.

Magnesium

Amount of food consumed had a significant positive effect on magnesium accounting for nearly 2% of the variance within animals and days. Time since feeding as a polynomial to the fourth power accounted for 4% of the variance. The shape of the curve (Fig. VII:4) with a fall after feeding, some minor changes and a rise to the initial level at the end is unexpected. Magnesium is absorbed principally through the rumen mucosa and a rise would be expected to occur after feeding. There are a number of factors which interfere with magnesium absorption as well as a number which involve magnesium homeostasis. Calcitonin does depress serum magnesium and it is possible that the raised level of calcitonin as discussed later in the section on calcium could have produced this effect. There was no significant effect of time of day and that of time since milking was very small.

Calcium

The effect of amount of food eaten was large positive and linear. This effect cannot easily be reconciled with the view that secretion of gastrin causes release of calcitonin which prevents post-prandial hypercalcaemia. On the other hand the shape of the polynomial describing the effect of time since food was offered (Fig. VII:6) on the level of calcium is consistent with this view of the role of gastrin. The effect of time since offering food is remarkably similar for both magnesium (Fig. VII:4) and calcium. On the other-hand calcium unlike magnesium has a significant diurnal variation accounting for approximately 17% of the within animal and day variance (Fig. VII:5). In this calcium resembles inorganic phosphate (Fig. VII:7). Time since milking has a significant but small (less than 2% of the variance) effect on level of calcium.

Inorganic Phosphate

Amount of food eaten is without effect on inorganic phosphate which contrasts with the major effect of this variable on calcium. The effect of time since food was offered was large (13.6% of the variance). The curve for this polynomial (Fig. VII:8) shows a fall after feeding, the rate of fall decreasing with greater time. There is no satisfactory explanation for this change. There is a quantity of phosphate in the saliva where it contributes extensively to the buffer system in the rumen (see Review of Literature). This would be expected to cause a more abrupt fall closer to feeding rather than the type of change illustrated in this curve.

The third order polynomial in time of day accounts for 10.4% of the variance of phosphate, and the shape of the curve (Fig. VII:7) approximates to that for calcium (Fig. VII:5) with a peak value about 0500 hours and a trough at about 1800 hours. No satisfactory explanation for this diurnal

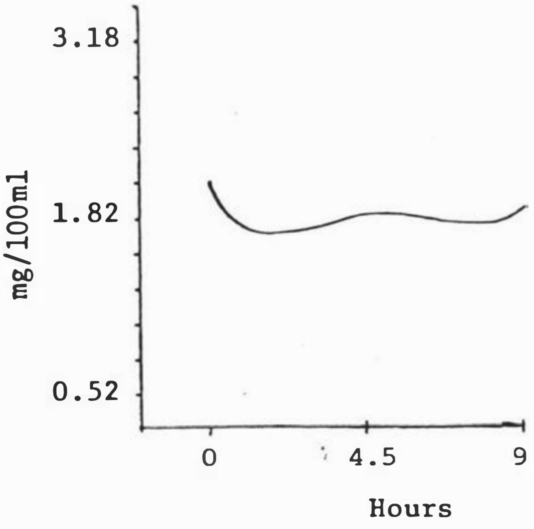

Figure VII:4

Magnesium
Time since feeding

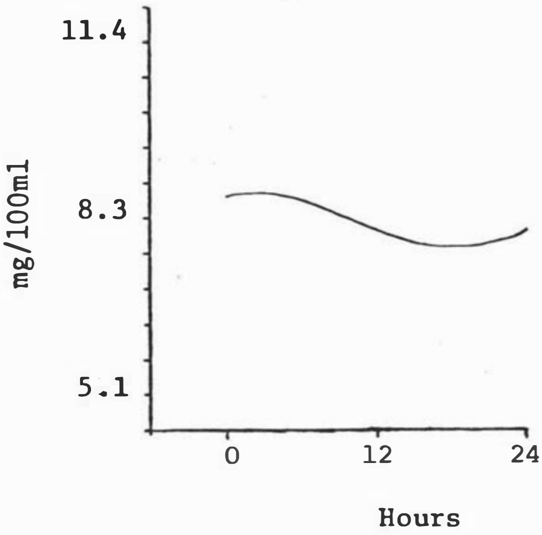

Figure VII:5

Calcium
Time of day

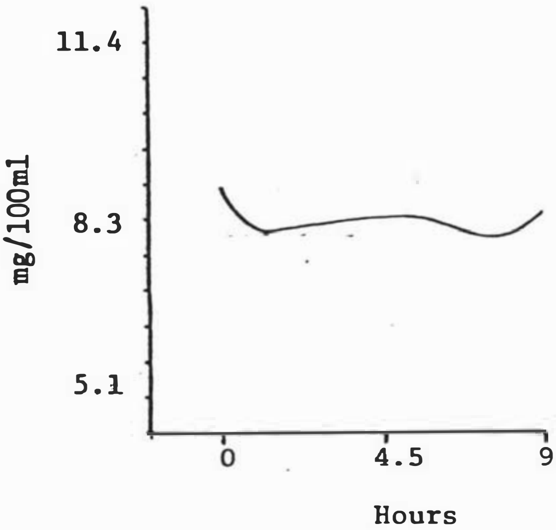

Figure VII:6

Calcium
Time since feeding

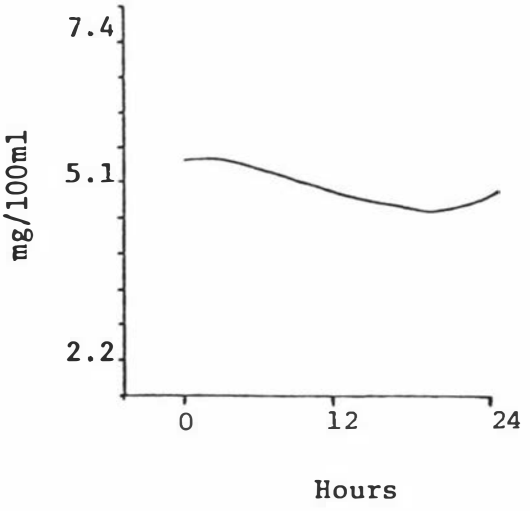

Figure VII:7

Inorganic phosphate
Time of day

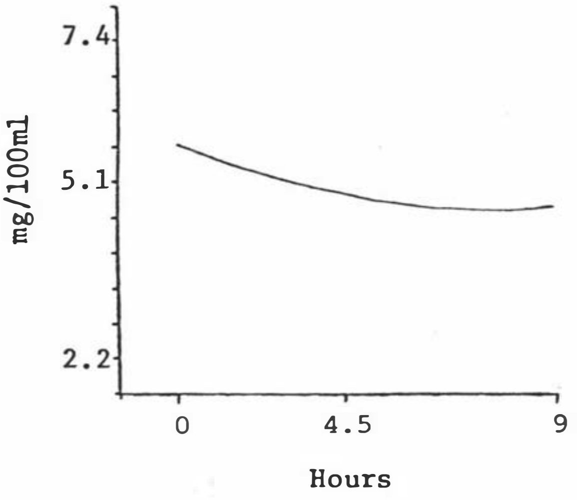

Figure VII:8

Inorganic phosphate
Time since feeding

pattern can be offered.

As with calcium there is a small effect of time since milking which explains about 2.3% of the variance.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

The study reported in this thesis was aimed at examining a metabolic profile for cattle in order to establish baseline data for New Zealand from which assessment of abnormality could be undertaken. To assist interpretation of the results attempts were made to evaluate the effects of some factors which could cause variation in the parameters that constituted this profile. The project was undertaken in four parts.

Part A involved the collection and analysis for haematocrit, haemoglobin, total protein, albumin, urea nitrogen, glucose, sodium, potassium, magnesium, calcium and inorganic phosphate of blood samples from groups of cattle on the three Massey dairy units two of which were seasonal supply herds and the other a town milk supply herd. Animals were selected to give a wide range in age, calving date and milk production. Each was followed as far as was possible for a twelve month period with samples being taken at four weekly intervals. Analysis of the data yielded information on the changes in the parameter associated with age, season and stage of lactation. The amount that season and lactation contributed individually to the variation observed was difficult to determine because of the concurrent nature of the changes that occur in both in a seasonal calving herd; the information obtained from the town milk supply herd which had cows calving at two seasons of the year was more helpful in this respect. Year means and standard deviations for the year were calculated for each parameter and compared with similar information reported in the literature from the U.K.

Part B of the project examined data collected from a seasonal dairy herd at another location in New Zealand (Awaroa) to determine what differences (if any) existed between two geographical areas a considerable distance apart. Since the samples for Part B were neither collected nor analyzed in the same year as those for Part A comparison of results required that between year as well as between locality variation had to be kept in mind since the two were confounded.

For Part C identical twin cattle from Unit 3 at Massey were used. They were bled on three consecutive days each month for thirteen months and the data analyzed to determine the amount of variation contributed by months, days, pairs, animals within pairs and their interactions to the total variation observed over the sampling period.

The final section, Part D, of the study involved sampling identical twin cattle in which indwelling catheters had been implanted, at two-hourly intervals for 12 days. These animals were housed during the sampling period and fed a mixture of dried grass and dried lucerne with water supplied *ad libitum*. Milking and feeding were carried out at staggered intervals so that each was varied relative to the other. The data were analyzed for effects associated with quantity of feed ingested, time of day, milking and feeding.

Two major problems were encountered with the catheterisation technique used in Part D of this study. The first involved the tracking of infection along the path of the catheter with the formation of subcutaneous abscesses. They were not observed until near the end of the second of the six day sampling cycles and no systemic signs accompanied their presence. The second was associated with the intravenous portion of the catheter causing trauma to the vein wall. This resulted in endophlebitis and other sequelae which ultimately led, over a prolonged period, to the death of 10 animals. Although the time sequence of these events was not measured the general health of the animals indicated that the effects of the damage to the vein were minimal over the sampling period and results from the first of the six day cycles were used in drawing conclusions. The effects of these problems notwithstanding the experimental design was intended to eliminate cross reactions between the sources of variation, i.e. time of day, time since milking and time since feeding. Examination of the results shows that this was achieved and that the influence of one source of variation was independent of the others. Nevertheless it would be desirable to repeat this particular part of the project using catheterisation techniques designed to eliminate these problems.

Mean Values for the Parameters Measured

The mean values derived in Parts A and B of the project bear in general a close similarity to each other but a less close relationship to the figures reported for metabolic profiles recorded in the U.K. (Tables IV:1 and V:1).

Differences in the blood levels of macro-elements such as sodium and potassium, which because of their role in osmoregulation would not be expected to vary in the normal animal, as well as calcium and phosphorus which have a wide range of homeostatic mechanisms designed to maintain their stability despite considerable change through the lactation and growing periods in respect to input and output, were relatively minor between the two countries. The relatively low phosphate levels observed in one New Zealand herd (Awaroa) could have been explained by the nature of the soil structure and the degree to which it was exposed to leaching on this particular property; this explanation is however speculative and requires clarification. Despite the relatively low phosphate values no evidence of clinical abnormalities attributable to phosphorus insufficiency were observed and they are considered to fall within the range of normal for the area.

The low magnesium levels noted in New Zealand cattle indicate their vulnerability to problems associated with hypomagnesaemia. It is suggested that greater variability of available magnesium in the diet with an all-pasture grazing system, together with the high seasonal demands in milk production (which peaks in seasonal factory supply herds during the late spring) would account for this difference between the two countries. Since the exact nature of the diets fed in the U.K. remain unknown however, this suggestion is again speculative.

The most marked difference in the parameters measured were noted with the haematocrit, haemoglobin, total protein, urea nitrogen and glucose. Relatively high values for total protein and blood urea nitrogen in New Zealand cattle are likely to be associated with the high levels of digestible protein in the pasture during the favourable growing periods that occur in this country; why the blood glucose levels should also be high remains unknown. Even more difficult to explain, in view of the apparently high energy and protein producing capacity of the diet fed, were the low values for haematocrit and haemoglobin, as well as the lower milk production per animal that occurs in New Zealand. The impact of the diverse husbandry systems between and within the two countries on these parameters, and the ability of the animal to produce, has yet to be adequately clarified. The means derived in this part of the project may serve as baseline data for a New Zealand metabolic profile until more is learned about minimum levels for the parameters and/or more data becomes available.

Genetic Influences

Clear evidence was obtained indicating that there was a significant measure of genetic control over the haematocrit and haemoglobin levels in cattle. A genetic contribution to the variation in urea nitrogen was also observed and to a lesser extent with total protein and albumin.

No genetic influence was noted for sodium and magnesium and only a small effect for glucose, potassium, calcium and inorganic phosphate.

Assessment of the heritability of the parameters under study was not attempted.

Age Effects

Inorganic phosphate fell with increasing age, an effect which was expected in view of the declining solubility of bone with advancing age; calcium which also would be expected to fall with age, showed no such decline. A diet replete in this mineral was suggested as the reason for this difference.

Increasing age was associated with an increasing level of globulin on the Massey units with albumin remaining relatively constant; little change due to age was observed on the Awaroa property. Since the changes in the level of globulin were not related to a high level of protein in the diet in older animals, as shown by the lack of change in the urea nitrogen level with increasing age, it is likely that the response was associated with increasing levels of gamma-globulin.

Other changes associated with age were minimal unless there was some other related problem such as the loss of temporary and eruption of permanent teeth (younger animals) and excessive tooth wear (older animals). These problems, associated with the social competitive pressures that exist within the herd with animals of these ages, could, by restricting grazing ability, result in lower values for glucose, haematocrit and haemoglobin.

Seasonal Effects

Variation with season occurred with most of the parameters measured although these effects tended to be minimal for sodium and especially potassium. In the case of magnesium, where evaluations are often directed at detecting changes which are clinically important, there was a low point in the winter and early spring followed by a rise to a peak in the summer and a fall again in the winter in the same manner as has often been recorded in the literature. Between-herd differences were noted. The extent of the seasonal variation in the other parameters, with the possible exception of the haematocrit and haemoglobin, while interesting, was not sufficient to make it important in interpreting the values obtained which were within two standard deviations of the annual mean.

Haematocrit and haemoglobin values followed a biphasic pattern with values which were low in the spring and autumn and high in the winter and summer. By some standards that have been outlined in the literature the percentage of animals having low values therefore varied with season, a feature which needs further examination before its implications in respect to productivity can be fully understood. It was noted that these changes tended to follow by a short period the alteration in pasture protein and this could be a likely source of this variation. Climatic effects brought about by temperature changes and/or the influence of lactation, which in a seasonally calving herd in New Zealand may be confounded with season, are other contributing factors requiring consideration.

Between herd differences in total protein and albumin values were noted between the Awaroa herd (little seasonal effect) and the Massey units where there was a rise during the summer. Part of this could be explained as a recovery from the outpouring of globulin in early lactation. More pronounced were the seasonal changes in urea nitrogen in all herds which tended to mimic the protein content of the diet. Some reduction in this positive response to high dietary protein was observed when underfeeding, particularly at high lactation levels, was in evidence.

Seasonal changes in plasma glucose levels were not marked; there was a fall during summer which could be a climatic effect associated with higher temperatures at this time, and a change on Unit 3 where glucose levels fell in response to periods of underfeeding.

The seasonal effects that were noticed with both calcium and phosphate, where a high point was reached in summer, probably relate to changes in the amounts of these elements in the diet although the influence of lactation cannot be disregarded.

Stage of Lactation

In general it appeared that where intake was sufficient to meet the added demands that lactation imposes on metabolism effects were minimal. Where changes did occur e.g. haematocrit, haemoglobin, calcium and phosphate, there tended to be a fall at the time of peak demand.

A fall in globulin levels occurred at the commencement of lactation as the udder filled with colostrum and recovery occurred over the succeeding 4 weeks.

As milk production rose to a peak albumin fell and globulin rose; this may serve to maintain constant plasma oncotic pressure.

Monthly Variation

As expected, month by month variation, which combined the effects of both season and lactation, was an important source of variation in all the parameters under study. In the cases of haematocrit, haemoglobin, total protein and urea nitrogen this is believed to be due to changes in the protein content of the pasture available for consumption.

With glucose this was the only major source of variation although the large interaction of pairs with months could indicate some degree of genetic control. Changes in the quantity and composition of the diet, and in management factors associated with the manner in which it is harvested, are the probable causes of such variation. Month by month variation was the largest source of variation for sodium, potassium, calcium and magnesium and a major source for inorganic phosphate. In all cases, as lactation seemed to produce relatively minor variations in the serum levels of these parameters, the effects are believed to be largely due to changes in the diet with season. Other factors associated with season cannot, however, be ruled out.

Daily Variation

This source of variation was relatively unimportant.

Diurnal Variation

Significant diurnal variation was observed with sodium, calcium and inorganic phosphate but it contributed in only a small way to the total variation observed with sodium. The reason and the manner in which such variation arises must await further investigation.

Amount of Feed Consumed

The amount of feed consumed caused considerable variation in haematocrit, haemoglobin, total protein, albumin and calcium. In the case of calcium this accounted for 20% of the variation. This relationship is important with respect to the influence of feeding level on metabolic profiles. In view of the published results (see Review of Literature) it was surprising that amount of food eaten had no effect on urea nitrogen, glucose, sodium and magnesium.

Time Since Feeding

This was the most important source of variation for haemoglobin and inorganic phosphate, and was moderately important for haematocrit and calcium. The amount of variation explained was low except in the case of haemoglobin and phosphate, thus time since animals have been fed is an important consideration if either of these parameters is included in the metabolic profile.

Time Since Milking

Significant but relatively unimportant changes were observed with haemoglobin, sodium and calcium. Time since milking may be regarded as of little consequence when sampling for a metabolic profile.

Application of Metabolic Profiles to Dairy Herds

Since the metabolic profile was introduced for cattle a number of suggestions have been published concerning its value. These range from its usefulness as a measure of the adequacy of a feeding regime, to the selection of genetically superior animals, the solution of disease problems which have not yielded to other means of diagnosis, and as a test procedure to evaluate new methods of husbandry and management. Although the technique has yielded helpful information, it has not provided all the results expected from it and other analyses, primarily based on the medical methodology available with advanced and sophisticated automated analytical equipment, have been carried out often without knowing the relevance of the parameter under examination. The significance of changes in attributes that are measured need to be determined as well as the effectiveness of the assay used, before their inclusion in a profile.

While other samples may give a better indication of the actual status of an element or compound in the animal e.g. saliva for sodium and bone biopsy for phosphate, the basis of a profile involves a blood sample because of its ease of collection and ease of standardisation of collection and handling procedures. It is therefore important to devise methods which will yield information that is useful for the parameters that are included. Central laboratory facilities may be necessary to eliminate between-laboratory differences and regular monitoring may be essential to provide adequate information on which to base a decision.

Of the parameters used in this study most have yielded useful information. A possible exception is that involving inorganic phosphate since in the U.K. it is the only parameter where no herd has been recorded with a mean outside the range they have used for normality. In New Zealand however, where phosphate deficiency has occasionally been recorded (Clark, 1974) it seems desirable that this estimation be continued.

The most disturbing feature of the investigation was how little of the total variation could be explained by the variables examined, with the residual variation remaining high. Problems with both sample handling and testing method were experienced and these are clearly factors that require further investigation and refinement. Controlled environmental conditions appear necessary in order to gain a better understanding of internal and external mechanisms of control. With cattle these could only be carried out at a high cost. Under New Zealand conditions where the main information that may be derived from the present parameters is whether the cattle are getting sufficient feed, the metabolic profile seems to lack adequate sensitivity when compared with other methods for achieving an answer to this question. Introduction of the test does not therefore seem justified other than on an experimental basis, until some of these studies have been carried out and an acceptable level of understanding achieved. Because of the changing status of micro-elements in the diet in this country they too may be worthy of closer investigation in future profile studies.

Although not primarily designed with this in mind, data obtained during the course of this study could be used for an investigation of the relationship that exists (if any) between production and fertility and the parameters measured. Since identical twins were used for the work in Part D it would also be possible to examine the heritability of the responses to the sources of variation investigated in that section of the project.

Clearly a great deal more research is needed before the potential of the metabolic profile as an aid to increasing productivity can be said to have been thoroughly explored.

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APPENDIX A

HAEMOGLOBIN

Ferricyanide - Cyanide Reagent:

(1)	Sodium bicarbonate	2.4 g
(2)	Potassium ferricyanide	2.4 g
(3)	Potassium cyanide	0.3 g
(4)	Distilled water qs	1000 ml

Keeps in amber bottle up to 1 week.

TOTAL PROTEIN

Biuret Reagent:

A. Alkaline Potassium Iodide:

(1)	Potassium iodide	5.0 g
(2)	Sodium hydroxide	8.0 g
(3)	Distilled water qs	1000 ml

B. Stock Biuret:

(1)	Sodium potassium tartrate	45 g
(2)	Copper sulphate	15 g
(3)	Potassium iodide	5 g
(4)	0.2 N Sodium hydroxide qs	1000 ml

C. Working Biuret:

(1)	Stock biuret	200 ml
(2)	Alkaline potassium iodide qs	1000 ml

Blank Solution:

(1)	Sodium potassium tartrate	9.0 g
(2)	Alkaline potassium iodide qs	1000 ml

Note: This reagent was used in place of working biuret reagent for determining blank values of serum samples. The protein equivalent of the blank colour was read from the protein standard curve and subtracted from the biuret value for each sample.

ALBUMIN

Working HABA Dye

A. Stock HABA Dye:

(1)	2-(4'-hydroxybenzeneazo)-benzoic acid	1.45 g
(2)	1-N Sodium hydroxide	10 ml
(3)	Distilled water qs	1000 ml

B. Phosphate Buffer:

(1)	Dipotassium hydrogen phosphate	8.4 g
(2)	Potassium dihydrogen phosphate	29.2 g
(3)	Distilled water qs	1000 ml

C. Working HABA Dye:

(1)	Stock HABA dye	100 ml
(2)	Phosphate buffer	250 ml
(3)	Distilled water qs	1000 ml

Note: If refrigerated between runs, the reagent is stable for at least three days. Before using bring to room temperature. The formation of particulate matter is a sign of deterioration.

Blank Solution

(1)	Stock phosphate buffer	250 ml
(2)	Distilled water qs	1000 ml

Note: This reagent was used in place of working HABA dye for determining blank values on serum samples. The albumin equivalent of the blank colour was read from the albumin standard curve and subtracted from the HABA value for each sample.

UREA NITROGEN

Working U.N. Colour Reagent

A. Stock Diacetyl Monoxime:

(1)	Diacetyl monoxime	25.0 g
(2)	Distilled water qs	1,000 ml

B. Stock Thiosemicarbazide:

(1)	Thiosemicarbazide	5.0 g
(2)	Distilled water qs	1,000 ml

C. Working U.N. Colour Reagent:

(1)	Stock diacetyl monoxime	67 ml
(2)	Stock thiosemicarbazide	67 ml
(3)	Distilled water qs	1,000 ml
(4)	30% Briz 35	0.5 ml

Working U.N. Acid Reagent

A. Stock Ferric Chloride - Phosphoric Acid:

(1)	Ferric chloride	15.0 g
(2)	Phosphoric acid (85%)	300 ml
(3)	Distilled water qs	450 ml

B. Stock Sulphuric Acid - 20%

(1)	Concentrated sulphuric acid	200 ml
(2)	Distilled water qs	1,000 ml

C. Working U.N. Acid:

(1)	Stock ferric chloride - phosphoric acid	1 ml
(2)	Stock sulphuric acid - 20% qs	1,000 ml

Stock Urea Nitrogen

A. Standard Diluent:

(1)	Phenyl mercuric acetate	0.20 g
(2)	Concentrated sulphuric acid	1.4 ml
(3)	Distilled water qs	5,000 ml

B. Stock Urea Nitrogen:

(1)	Urea	21.433 g
(2)	Standard diluent qs	1,000 ml

GLUCOSE

Potassium Cyanide Reagent

(1)	Sodium chloride	9.0 g
(2)	Potassium cyanide	5.0 g
(3)	Distilled water qs	1,000 ml
(4)	30% Brij 35	0.5 ml

Alkaline Potassium Ferricyanide Reagent

(1)	Sodium chloride	9.0 g
(2)	Potassium ferricyanide	0.25g
(3)	Sodium carbonate (anhyd)	20.0 g
(4)	Distilled water qs	1,000 ml
(5)	30% Brij 35	0.5 ml

Stock Glucose 10mg/ml

5.0g dextrose in 500 ml saturated benzoic acid solution.

Working Standards

Std No.	ml Stock Glucose	ml Stock Urea	mg/100ml Glucose	mg/100ml U.N.
1	2	0.5	20	5
2	3	1	30	10
3	4	2	40	20
4	5	3	50	30
5	6	4	60	40
6	7	5	70	50

When diluted to 100ml with distilled water the working standards contained the indicated concentrations of glucose and urea nitrogen.

SODIUM AND POTASSIUM

Lithium Nitrate Solution

A. Stock Solution:

(1)	Lithium nitrate	69.08 g
(2)	Concentrated sulphuric acid	98 ml
(3)	Distilled water qs	1,000 ml

B. Working Solution:

(1)	Stock lithium nitrate	125 ml
(2)	Distilled water qs	1,000 ml
(3)	30% Brij 35	0.5 ml

Stock Sodium Standard (1,000mEq/l)

(1)	Sodium chloride	58.45 g
(2)	Distilled water qs	1,000 ml

Stock Potassium Standard (100mEq/l)

(1)	Potassium chloride	7.456g
(2)	Distilled water qs	1,000 ml

Working Standards

Std No.	ml Stock Sodium	ml Stock Potassium	mEq/l Sodium	Potassium
1	10	8	100	8
2	11	8	110	8
3	12	8	120	8
4	13	2	130	2
5	14	4	140	4
6	15	6	150	6
7	16	8	160	8

When diluted to 100ml with distilled water the working standards contained the indicated concentrations of sodium and potassium.

MAGNESIUM

Strontium Solution

(1)	Strontium nitrate	2.5 g
(2)	Distilled water qs	1,000 ml

Stock Magnesium Solution

This was prepared by dissolving 1.056g of magnesium metal in a minimum quantity of concentrated hydrochloric acid and diluting to 100ml with distilled water. A second dilution of 1 in 100 was made with the strontium solution. The working standards were prepared from this by diluting 0.5, 1.0, 1.5 and 2.0 ml to 10 ml volume with the strontium solution to give solutions to 0.5, 1.0, 1.5 and 2.0 ppm respectively.

CALCIUM

0.25 N Hydrochloric Acid

(1)	Concentrated hydrochloric acid	21 ml
(2)	Distilled water qs	1,000 ml
(3)	30% Brij 35	0.5 ml

Cresolphthalein Complexone and 8-Hydroxyquinoline

(1)	Cresolphthalein complexone	0.10 g
(2)	8-hydroxyquinoline	2.5 g
(3)	0.25 N hydrochloric acid qs	1,000 ml

Calcium Base

(1)	Diethylamine	37.5 ml
(2)	Potassium cyanide	0.125 g
(3)	Distilled water qs	1,000 ml

Note: During the use of this test some loss of sensitivity was noted. It was found that insufficient base was the problem. To overcome this the amount of diethylamine in this reagent was increased from 37.5 to 50 ml.

Stock Calcium Solution (50mg/100ml)

(1)	Calcium carbonate	2.50 g
(2)	Concentrated hydrochloric acid	14.5 ml
(3)	Distilled water qs	2,000 ml

INORGANIC PHOSPHATE

0.25 N Hydrochloric Acid

(1)	Concentrated hydrochloric acid	21 ml
(2)	Distilled water qs	1,000 ml
(3)	Wetting agent A	2 ml

Stannous Chloride - Hydrazine Sulphate

A. 0.2% Hydrazine Sulphate in 1 N Sulphuric Acid:

(1)	Hydrazine sulphate	4.0 g
(2)	Concentrated sulphuric acid	56 ml
(3)	Distilled water qs	2,000 ml

B. Working Solution:

(1)	Stannous chloride	200 mg
(2)	0.2% hydrazine sulphate in 1 N sulphuric acid, qs	1,000 ml

Note: This reagent may be stored at room temperature for at least one week but deterioration may occur past this time.

Acidic Ammonium Molybdate

(1)	Ammonium molybdate	10 g
(2)	Concentrated sulphuric acid	35 ml
(3)	Distilled water qs	1,000 ml

Stock Phosphate Solution

(1)	Monobasic potassium phosphate	4.381 g
(2)	Distilled water qs	1,000 ml

Stock Magnesium Solution

(1)	Magnesium chloride	8.36 g
(2)	Distilled water qs	1,000 ml

ml Stock Calcium	ml Stock Phosphorous	ml Stock Magnesium	mg/100 ml		
			Ca	P	Mg
10	1	2	5	1	2
15	3	2	7.5	3	2
20	5	2	10	5	2
25	7	2	12.5	7	2
30	10	2	15	10	2

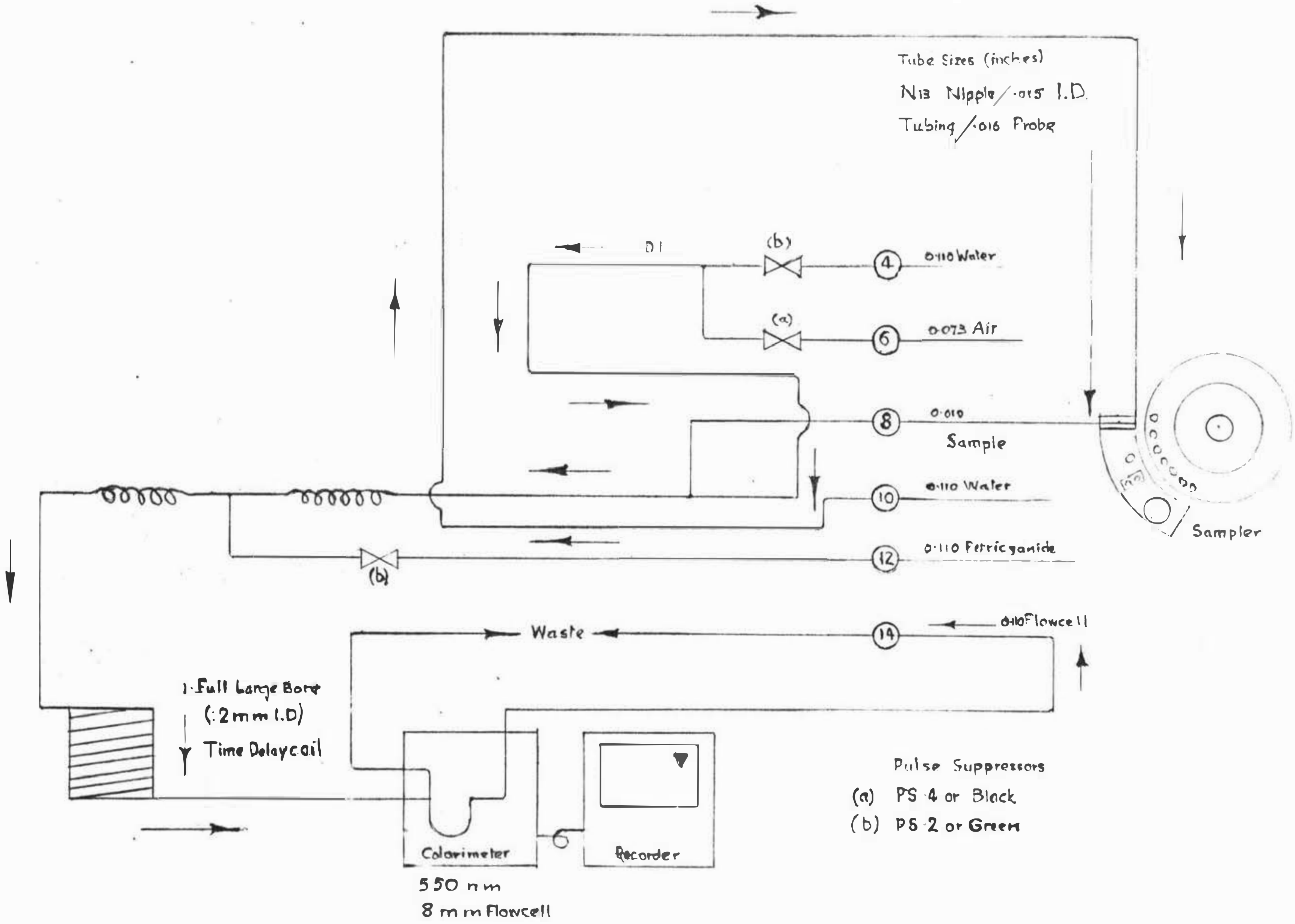
When diluted to 100 ml with distilled water the working standards contained the indicated concentrations of calcium, phosphorus and magnesium. The magnesium was included in the standards because of some residual interference if the sample contained magnesium.

Special Maintenance

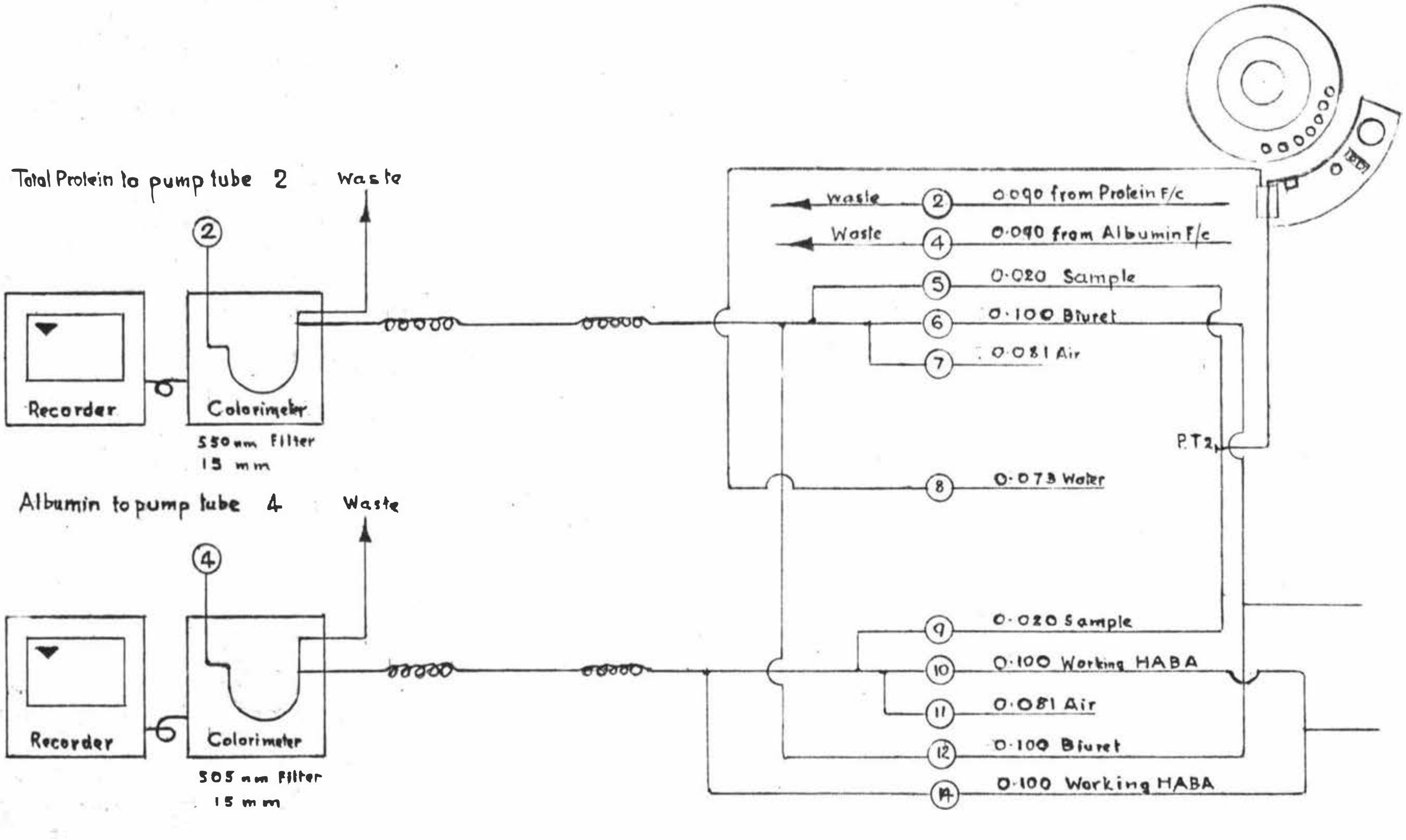
The phosphate channel was flushed regularly after use with 1 M sodium hydroxide to remove any traces of blue precipitate. The alkali was run through the stannous chloride - hydrazine sulphate and acidic ammonium molybdate lines for ten minutes followed with a ten minute water wash.

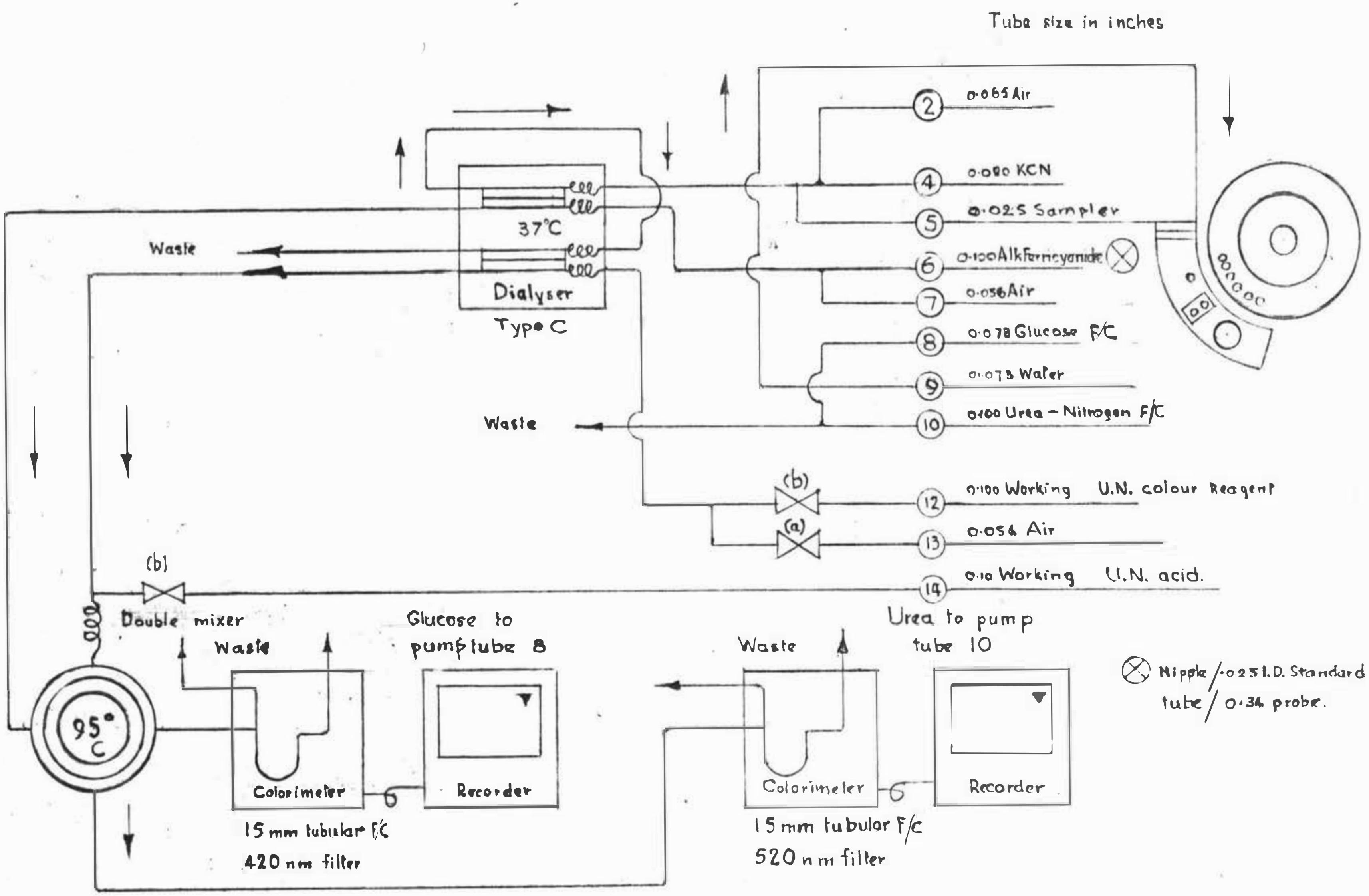
APPENDIX B

HAEMOGLOBIN



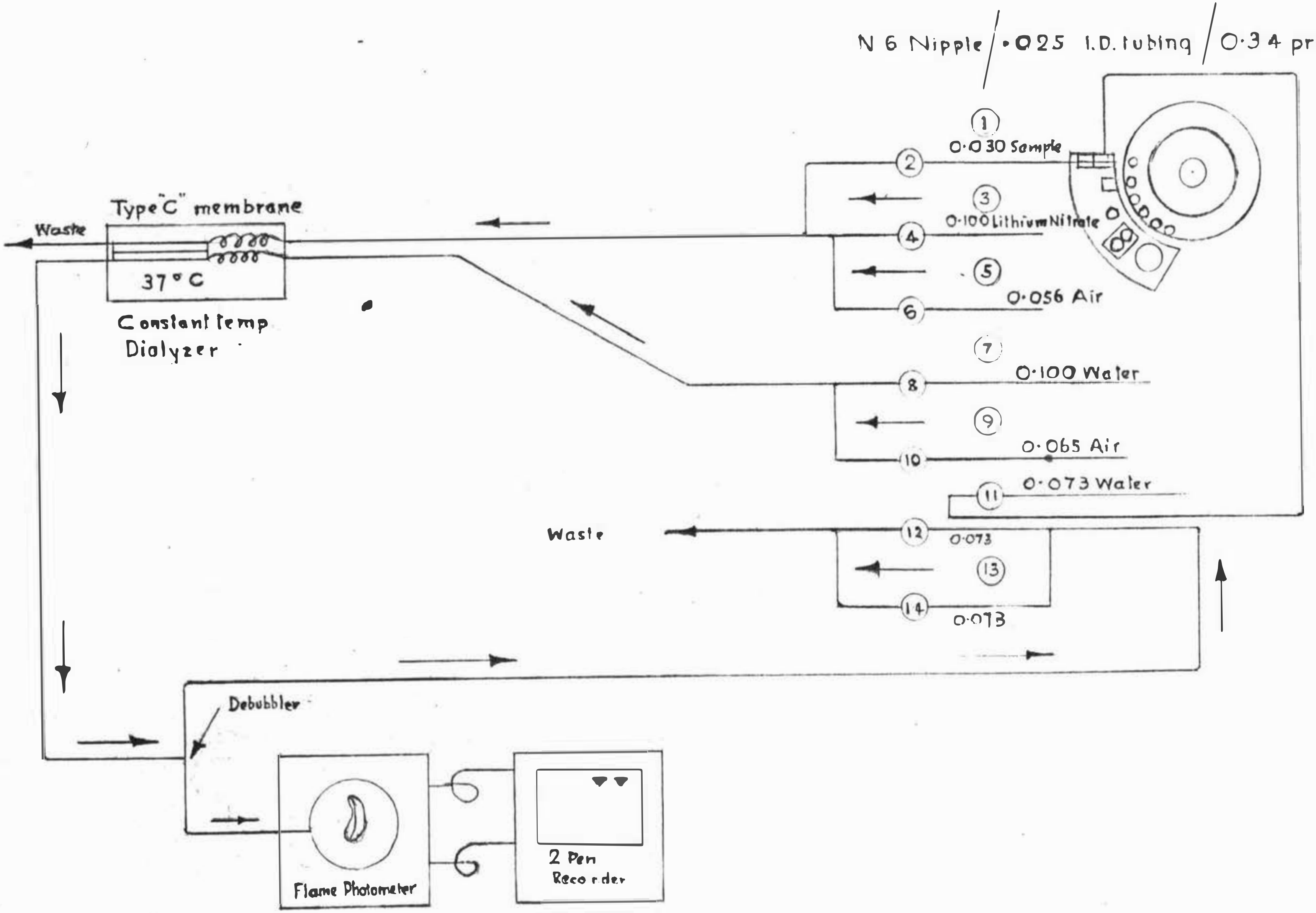
SIMULTANEOUS TOTAL PROTEIN AND ALBUMIN



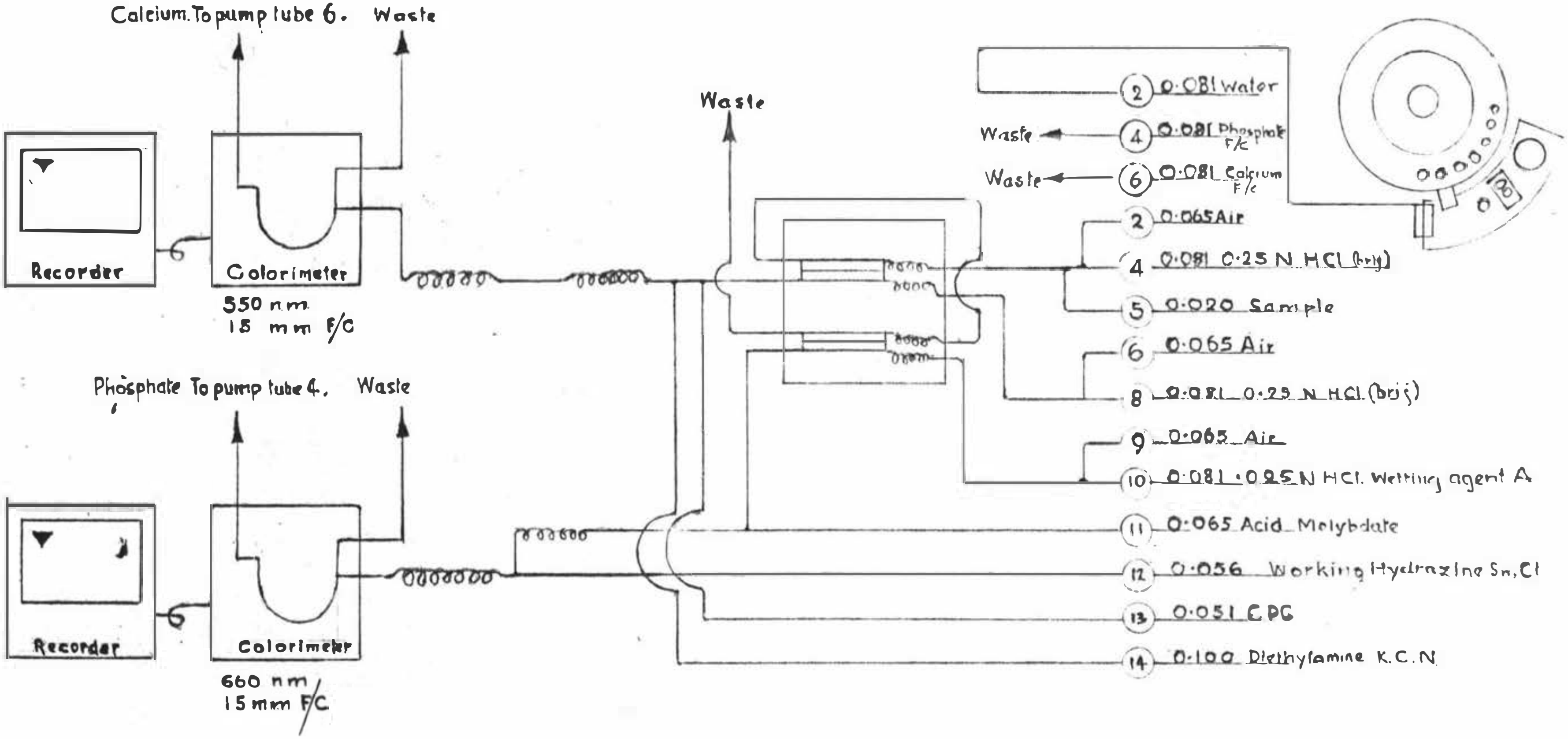


SIMULTANEOUS GLUCOSE-UREA NITROGEN

SODIUM & POTASSIUM



SIMULTANEOUS CALCIUM AND INORGANIC PHOSPHATE



APPENDIX C

MEANS OF PARAMETERS DERIVED FROM PART C OF THE STUDY

Haematocrit	%	27.2
Haemoglobin	g/100ml	11.4
Total protein	g/100ml	7.4
Albumin	g/100ml	3.7
Urea nitrogen	mg/100ml	23.0
Glucose	mg/100ml	61.1
Sodium	mEq/l	140.4
Potassium	mEq/l	5.4
Magnesium	mg/100ml	2.3
Calcium	mg/100ml	10.0
Inorganic Phosphate	mg/100ml	6.9

Note: Deriving the above values was not the main objective of Part C of the project - hence their inclusion as an appendix. The values for sodium are considered to be more reliable than earlier values obtained for the Massey units as problems involving analytical technique had been overcome when these were run.

TABLE C:2

SUMMARY OF THE PROCEDURE USED TO ESTIMATE COMPONENTS OF VARIANCE

SOURCE OF VARIATION	DEGREES OF FREEDOM	EXPECTED MEAN SQUARE	ESTIMATE OF VARIANCE COMPONENT
Months	$(m-1) = 12$	$M_M = \sigma^2 + p\,d\,a\,\sigma^2_M$	$\sigma^2_M = (M_M - M_R)/42$
Pairs	$(p-1) = 6$	$M_P = \sigma^2 + m\,a\,\sigma^2_{PD(M)} + m\,d\,a\,\sigma^2_P$	$\sigma^2_P = (M_P - M_{PD(M)})/78$
Months x pairs	$(m-1)(p-1) = 72$	$M_{MP} = \sigma^2 + d\,a\,\sigma^2_{MP}$	$\sigma^2_{MP} = (M_{MP} - M_R)/6$
Days(months)*	$m(d-1) = 26$	$M_{D(M)} = \sigma^2 + m\,p\,a\,\sigma^2_{D(M)}$	$\sigma^2_{D(M)} = (M_{D(M)} - M_R)/182$
Animals(pairs)†	$p(a-1) = 7$	$M_{A(P)} = \sigma^2 + m\,p\,d\,\sigma^2$	$\sigma^2_{A(P)} = (M_{A(P)} - M_R)/273$
Months x animals(pairs)	$(m-1)p(a-1) = 84$	$M_{MA(P)} = \sigma^2 + d\,p\,\sigma^2_{MA(P)}$	$\sigma^2_{MA(P)} = (M_{MA(P)} - M_R)/21$
Pairs x days(months)	$(p-1)m(d-1) = 156$	$M_{PD(M)} = \sigma^2 + m\,a\,\sigma^2_{PD(M)}$	$\sigma^2_{PD(M)} = (M_{PD(M)} - M_R)/26$
Residual§	$m(d-1)p(a-1) = 182$	$M_R = \sigma^2$	$\sigma^2 = M_R$

* Days within months (nested effect)

† Animals within pairs (nested effect)

§ Days within months x animals within pairs (interaction of two nested effects). This mean square was used as the denominator for F-tests of the other mean squares, with the exception of that for the effect of Pairs where the denominator was the mean square for Pairs x days(months).

Components of variance were not estimated for effects where the mean square was non-significant ($p > 0.05$)

TABLE C:3 CORRELATIONS BETWEEN HAEMATOCRIT AND HAEMOGLOBIN AND THE OTHER VARIABLES

Variable / Cow	x12	x13	x14	x15	x16	x17	x18	x19	x20
123 x 10	-0.0926	-0.1831	0.0093	0.0598	0.0632	-0.1041	-0.0129	-0.2144	-0.3311
123 x 11	0.1287	-0.0277	0.1519	0.1073	-0.0564	0.1085	-0.0966	0.3225	0.4472
124 x 10	0.0885	-0.0335	0.0847	-0.0892	-0.1113	0.0173	0.0208	0.0401	-0.1532
124 x 11	0.1410	-0.0960	0.0461	0.2265	0.0634	0.0312	-0.1408	0.1083	0.2169
125 x 10	0.0427	0.1211	0.8382	0.8653	0.8359	-0.6008	-0.5796	-0.3712	-0.4482
125 x 11	0.2774	-0.2024	-0.2235	-0.5466	-0.4582	0.4104	0.3007	0.2627	0.1003
126 x 10	-0.0491	-0.0896	0.0907	-0.0567	0.0068	0.0613	-0.1415	-0.0077	0.0563
126 x 11	0.1549	-0.0515	0.0700	-0.0208	-0.1583	0.1998	0.3647	0.3383	0.2001
131 x 10	0.3597	0.1988	0.1696	0.0485	-0.1479	0.0625	-0.2204	0.0536	-0.0539
131 x 11	-0.2188	-0.1626	0.1146	-0.3123	0.1017	-0.0613	0.4146	0.1882	0.2642
132 x 10	0.1676	0.1158	-0.0632	0.1568	0.1579	-0.1230	-0.1268	0.1148	-0.0699
132 x 11	-0.0505	-0.697	0.2850	-0.0620	-0.0044	-0.0305	0.1771	-0.0254	0.0477
137 x 10	0.3120	-0.0113	-0.0423	0.0008	-0.1952	-0.0484	-0.0070	0.1392	0.1484
137 x 11	0.1012	0.0930	0.0298	0.1844	-0.0214	-0.0087	0.0321	0.0594	0.1195
138 x 10	0.0058	-0.1305	0.4208	-0.1101	-0.0516	0.3481	0.1821	0.2302	0.2035
138 x 11	0.0217	0.0371	-0.2554	0.0469	-0.0445	-0.0416	0.0089	0.0589	0.0975
139 x 10	-0.2969	-0.1999	0.0945	0.0529	0.0818	-0.0594	0.0271	0.0921	-0.0065
139 x 11	0.3377	0.1026	-0.0205	-0.0945	0.1195	0.3515	0.2629	0.0722	0.1577
140 x 10	0.0305	0.0028	0.1015	0.0281	0.1285	-0.0614	-0.2462	-0.0237	-0.2501
140 x 11	0.0591	-0.2488	0.1085	-0.0799	-0.2395	0.2142	0.3060	0.1318	0.1912
141 x 10	0.3340	0.2245	0.0683	-0.2758	-0.4443	0.5241	0.5929	0.4917	0.1274
141 x 11	-0.1272	-0.0549	0.2565	0.2823	0.1141	0.0531	-0.1954	0.0780	0.0459
142 x 10	0.1093	0.0963	0.3353	-0.1732	-0.0498	0.2935	0.2319	0.1956	0.1816
142 x 11	0.1918	-0.0777	-0.0954	0.1206	-0.0799	-0.0787	-0.0579	-0.0305	0.1363
147 x 10	0.3074	0.1314	-0.0857	-0.1512	-0.0890	0.1287	0.3357	0.4664	0.2340
147 x 11	-0.3015	-0.1635	0.1002	0.2387	0.0076	0.0815	-0.0196	-0.0730	0.2197
148 x 10	0.3455	0.2559	0.1624	0.0509	-0.0220	0.0296	0.0560	0.1969	-0.0355
148 x 11	-0.0062	-0.1827	0.1256	0.0231	-0.0770	0.1036	0.1466	0.0037	0.0188

x 10 indicates relationship of haematocrit and x 11 that of haemoglobin with the other variables x 12 to x 20.

TABLE C:4 : CORRELATIONS BETWEEN HAEMATOCRIT AND THE OTHER VARIABLES

Variable Cow	x12	x13	x14	x15	x16	x17	x18	x19	x20
123	-0.0926	-0.1831	0.0093	0.0598	0.0632	-0.1041	-0.0129	-0.2144	-0.3311
124	0.0885	-0.0335	0.0847	-0.0892	-0.1113	0.0173	0.0208	0.0401	-0.1532
125	0.0427	0.1211	0.8382	0.8653	0.8359	-0.6008	-0.5796	-0.3712	-0.4482
126	-0.0491	-0.0896	-0.0907	-0.0567	0.0068	0.0613	-0.1415	-0.0077	0.0563
131	0.3597	0.1988	0.1696	0.0485	-0.1479	0.0625	-0.2204	0.0536	-0.0539
132	0.1676	0.1158	-0.0632	0.1568	0.1579	-0.1230	-0.1268	0.1148	-0.0699
137	0.3120	-0.0113	-0.0423	0.0008	-0.1952	-0.0484	-0.0070	0.1392	0.1484
138	0.0058	-0.1305	0.4208	-0.1101	-0.0516	0.3481	0.1821	0.2302	0.2035
139	-0.2969	-0.1999	0.0945	0.0529	0.0818	-0.0594	0.0271	0.0921	-0.0065
140	0.0395	0.0028	0.1015	0.0281	0.1285	-0.0614	-0.2462	-0.0237	-0.2501
141	0.3340	0.2245	0.0683	-0.2758	-0.4443	0.5241	0.5929	0.4917	0.1274
142	0.1093	0.0963	0.3353	-0.1732	-0.0498	0.2935	0.2319	0.1956	0.1816
147	0.3074	0.1314	-0.0857	-0.1512	-0.0890	0.1282	0.3357	0.4464	0.2340
148	0.3455	0.2559	0.1624	0.0509	-0.0220	0.0296	0.0560	0.1969	-0.0355

TABLE C:5 CORRELATION BETWEEN HAEMOGLOBIN AND THE OTHER VARIABLES

Variable Cow	x12	x13	x14	x15	x16	x17	x18	x19	x20
123	0.1287	-0.0277	0.1519	0.1073	-0.0564	0.1085	-0.0966	0.3225	0.4472
124	0.1410	-0.0960	-0.0461	0.2265	0.0634	0.0312	-0.1408	0.1083	0.2169
125	0.2774	-0.2024	-0.2235	-0.5466	-0.4582	0.4104	0.3007	0.2627	0.1003
126	0.1549	-0.0515	0.0700	-0.0208	-0.1583	0.1998	0.3647	0.3383	0.2001
131	-0.2188	-0.1626	0.1146	-0.3123	0.1017	-0.0613	0.4146	0.1882	0.2642
132	-0.0505	-0.0697	0.2850	-0.0620	-0.0044	-0.0305	0.1771	-0.0254	0.0477
137	0.1012	0.0930	0.0298	0.1844	-0.0214	-0.0087	0.0321	0.0594	0.1195
138	0.0217	0.0371	-0.2554	0.0469	-0.0445	-0.0416	0.0089	0.0589	0.0975
139	0.3377	0.1026	-0.0205	-0.0945	0.1195	0.3515	0.2629	0.0722	0.1577
140	0.0591	-0.2488	0.1085	-0.0799	-0.2395	0.2142	0.3060	0.1318	0.1912
141	-0.1272	-0.0549	0.2565	0.2823	0.1141	0.0531	-0.1954	0.0780	0.0459
142	0.1918	-0.0777	-0.0954	0.1206	-0.0799	-0.0787	-0.0579	-0.0305	0.1363
147	-0.3015	-0.1635	0.1002	0.2387	0.0076	0.0815	-0.0196	-0.0730	0.2197
148	-0.0062	-0.1827	0.1256	0.0231	-0.0770	0.1036	0.1466	0.0037	0.0188

APPENDIX D

TABLE D:1

HAEMATOCRIT: ANALYSES OF VARIANCE SHOWING THE EFFECTS OF REGRESSION EQUATIONS WITH INDEPENDENT VARIABLES POWERS OF AMOUNT OF FEED CONSUMED (X_1), TIME SINCE FEEDING (X_2), AND TIME SINCE MILKING (X_3)

Source of Variation (Variables in order of insertion in the equation)		Mean Square	
		Full Equation	Reduced Equation
Effect of fitting	X_1	31840.44***	31840.44***
Additional effect of:	X_2	8194.77***	8194.77***
	X_3	1538.96	---
	X_2^2	11064.98***	10925.25***
	X_2^3	6794.75***	6642.48***
	X_2^4	562.00	---
	X_3	---	1083.97
	X_3^2	1423.58	1476.62
	X_3^3	4518.02**	4162.93**
	X_3^4	1431.39	---
Effect of all fitted variables		7565.43***	9399.97***
Residual (d.f. = 642-k)†		433.22	435.47

	Coefficient of Determination (Multiple correlation squared)	
R^2	.248	.237
$\overline{R}^2$ (corrected R^2) §	.237	.229

* $0.01 < p < 0.05$ ** $0.001 < p < 0.01$ *** $p < 0.001$

† k is the number of variables fitted in the equation

§ $\overline{R}^2 = 1 - 642(1 - R^2)/(642-k)$ is the best estimate of the proportion of variance of the dependent variable 'explained' by the fitted equation

TABLE D:2

HAEMOGLOBIN: ANALYSES OF VARIANCE SHOWING THE EFFECTS OF REGRESSION EQUATIONS WITH INDEPENDENT VARIABLES POWERS OF AMOUNT OF FEED CONSUMED (X_1), TIME SINCE FEEDING (X_2) AND TIME SINCE MILKING (X_3)

Source of Variation (Variables in order of insertion in the equation)		Mean Square Full Equation	 Reduced Equation
Effect of fitting	X_1	11758.89***	11758.89***
Additional effect of:	X_2	3359.86***	3359.86***
	X_3	159.77	---
	X_2^2	2106.36***	2086.39***
	X_2^3	2816.37***	2783.40***
	X_2^4	625.41*	576.84*
	X_3^2	414.47*	---
	X_3^3	250.35	---
	X_3^4	84.72	---
Effect of all fitted variables		2397.36	4113.08
Residual (d.f. = 642-k)†		106.70	107.62

	Coefficient of Determination (Multiple correlation squared)	
R^2	.319	.300
$\bar{R}^2$(corrected R^2) §	.309	.294

See Table D:1 for footnotes

TABLE D:3

SERUM TOTAL PROTEIN: ANALYSES OF VARIANCE SHOWING THE EFFECTS OF REGRESSION EQUATIONS WITH INDEPENDENT VARIABLES POWERS OF AMOUNT OF FEED CONSUMED (X_1), TIME SINCE FEEDING (X_2) AND TIME SINCE MILKING (X_3)

Source of Variation (Variables in order of insertion in the equation)		Mean Square Full Equation	Reduced Equation
Effect of fitting	X_1	1168.440***	1168.440***
Additional effect of:	X_2	---	.450
	X_3	---	.691
	X_2^2	---	6.645
	X_2^3	---	.028
	X_2^4	---	4.086
	X_3^2	---	2.339
	X_3^3	---	1.315
	X_3^4	---	4.896
Effect of all fitted variables		1168.440***	132.099***
Residual (d.f. = 642-k)†		17.812	18.005
		Coefficient of Determination (Multiple correlation squared)	
	R^2	.104	.103
	$\bar{R}^2$ (corrected R^2) §	.091	.102

See Table D:1 for footnotes

TABLE D:4

ALBUMIN: ANALYSES OF VARIANCE SHOWING THE EFFECTS OF REGRESSION EQUATIONS WITH INDEPENDENT VARIABLES POWERS OF AMOUNT OF FEED EATEN (X_1), TIME SINCE FEEDING (X_2), TIME SINCE MILKING (X_3) AND TIME OF DAY (X_4)

Source of Variation (Variables in order of insertion in the equation)		Mean Square Full Equation	Mean Square Reduced Equation
Effect of fitting	X_1	1978.298***	1978.298***
Additional effect of:	X_2	1.145	1.145
	X_3	40.184	---
	X_2^2	32.013	30.696
	X_2^3	37.653	39.216
	X_2^4	102.414	99.756
	X_3^2	9.218	---
	X_3^3	40.400	---
	X_3^4	1.826	---
	X_4	17.758	---
	X_4^2	1.580	---
	X_4^3	90.528	---
	X_4^4	15.606	---
Effect of all fitted variables		182.202***	432.333***
Residual (d.f. = 642-k)†		30.913	30.850

	Coefficient of Determination (Multiple correlation squared) Full Equation	Coefficient of Determination (Multiple correlation squared) Reduced Equation
R^2	.122	.110
$\overline{R}^2$ (corrected R^2) §	.103	.103

See Table D:1 for footnotes

TABLE D:5

UREA NITROGEN: ANALYSES OF VARIANCE SHOWING THE EFFECTS OF REGRESSION EQUATIONS WITH INDEPENDENT VARIABLES POWERS OF AMOUNT OF FEED EATEN (X_1), TIME SINCE FEEDING (X_2) AND TIME SINCE MILKING (X_3)

Source of Variation (Variables in order of insertion in the equation)		Mean Square Full Equation	 Reduced Equation
Effect of fitting	X_1	3.4	---
Additional effect of:	X_2	19596.5**	19410.2**
	X_3	173.9	---
	X_2^2	4861.2	4993.7
	X_2^3	9772.7*	9709.1*
	X_2^4	1087.8	---
	X_3^2	112.2	---
	X_3^3	37.0	---
	X_3^4	745.1	---
Effect of all fitted variables		4044.4	11371.0**
Residual (d.f. = 642-k)†		2446.0	2426.6

	Coefficient of Determination (Multiple correlation squared)	
R^2	.024	.022
$\overline{R}^2$ (corrected R^2)§	.010	.017

See Table D:1 for footnotes

TABLE D:6

GLUCOSE: ANALYSES OF VARIANCE SHOWING THE EFFECTS OF REGRESSION EQUATIONS WITH INDEPENDENT VARIABLES POWERS OF AMOUNT OF FEED EATEN (X_1), TIME SINCE FEEDING (X_2) AND TIME SINCE MILKING (X_3)

Source of Variation (Variables in order of insertion in the equation)		Mean Square Full Equation	 Reduced Equation
Effect of fitting	X_1	67057.0*	67057.0*
Additional effect of:	X_2	294119.0***	294119.0***
	X_3	83669.0**	---
	X_2^2	639.0	943.0
	X_2^3	70776.0*	67772.0*
	X_2^4	2217.0	---
	X_3	---	86369.0**
	X_3^2	7486.0	---
	X_3^3	14071.0	---
	X_3^4	20442.0	---
Effect of all fitted variables		62275.0***	103252.0***
Residual (d.f. = 642-k)†		12219.3	12214.9

	Coefficient of Determination (Multiple correlation squared)	
R^2	.072	.077
$\bar{R}^2$(corrected R^2)§	.068	.059

See Table D:1 for footnotes

TABLE D:7

SODIUM: ANALYSES OF VARIANCE SHOWING THE EFFECTS OF REGRESSION EQUATIONS WITH INDEPENDENT VARIABLES POWERS OF AMOUNT OF FEED EATEN (X_1), TIME SINCE FEEDING (X_2), TIME SINCE MILKING (X_3) AND TIME OF DAY (X_4)

Source of Variation (Variables in order of their insertion in the equation)		Mean Square Full Equation	Mean Square Reduced Equation
Effect of fitting	X_1	97.206*	97.206*
Additional Effect of:	X_2	35.379	35.379
	X_3	43.268	---
	X_2^2	1.004	.795
	X_2^3	123.721**	120.804**
	X_2^4	40.936	---
	X_3	---	46.395
	X_3^2	54.538	57.616
	X_3^3	.005	.466
	X_3^4	175.328**	167.950**
	X_4	217.190***	235.175***
	X_4^2	18.282	16.245
	X_4^3	112.568**	99.847*
	X_4^4	137.101**	124.950**
Effect of all fitted variables		81.217***	83.569***
Residual (d.f. = 642-k)†		15.662	15.697

	Coefficient of Determination (Multiple correlation squared) Full Equation	Reduced Equation
R^2	.099	.101
$\overline{R}^2$(corrected R^2) §	.082	.084

See Table D:1 for footnotes

TABLE D:8

POTASSIUM: ANALYSES OF VARIANCE SHOWING THE EFFECTS OF REGRESSION EQUATIONS WITH INDEPENDENT VARIABLES THE POWERS OF AMOUNT OF FEED EATEN (X_1), TIME SINCE FEEDING (X_2), TIME SINCE MILKING (X_3) AND TIME OF DAY (X_4)

Source of Variation (Variables in order of their insertion in the equation)		Mean Square Full Equation	Mean Square Reduced Equation
Effect of fitting	X_1	215.878**	215.878**
Additional effect of:	X_2	45.247	45.247
	X_3	66.025	---
	X_2^2	5.822	5.141
	X_2^3	362.319***	356.135***
	X_2^4	6.066	---
	X_3	---	72.890
	X_3^2	12.874	13.426
	X_3^3	9.006	10.420
	X_3^4	75.564	73.876
	X_4	217.516**	225.721**
	X_4^2	142.065*	134.057*
	X_4^3	32.478	33.572
	X_4^4	3.104	---
Effect of all fitted variables		91.859***	107.851***
Residual (d.f. = 642-k) †		23.731	23.669

Coefficient of Determination

(Multiple correlation squared)

	Full Equation	Reduced Equation
R^2	.080	.079
$\overline{R}^2$ (corrected R^2)§	.061	.063

See Table D:1 for footnotes

TABLE D:9

MAGNESIUM: ANALYSES OF VARIANCE SHOWING THE EFFECTS OF REGRESSION EQUATIONS WITH INDEPENDENT VARIABLES POWERS OF AMOUNT OF FEED EATEN (X_1), TIME SINCE FEEDING (X_2) AND TIME SINCE MILKING (X_3)

Source of Variation (Variables in order of their insertion in the equation)		Mean Square Full Equation	Mean Square Reduced Equation
Effect of fitting	X_1	38031.8**	38031.8**
Additional effect of:	X_2	11666.9*	11666.9*
	X_3	68.7	---
	X_2^2	23253.1**	23294.7**
	X_2^3	32450.3**	32474.8**
	X_2^4	35118.2**	35043.2**
	X_3	---	77.8
	X_3^2	2057.6	2057.0
	X_3^3	11149.6*	11148.7*
	X_3^4	389.1	---
Effect of all fitted variables		17131.7***	19224.4***
RESIDUAL (d.f. = 642-k)†		3625.7	3620.6

	Coefficient of Determination (Multiple correlation squared)	
R^2	.067	.067
$\overline{R}^2$(corrected R^2) §	.054	.055

See Table D:1 for footnotes

TABLE D:10

CALCIUM: ANALYSES OF VARIANCE SHOWING THE EFFECTS OF REGRESSION EQUATIONS WITH INDEPENDENT VARIABLES THE POWERS OF AMOUNT OF FEED EATEN (X_1), TIME SINCE FEEDING (X_2), TIME SINCE MILKING (X_3) AND TIME OF DAY (X_4)

Source of Variation (Variables in order of their insertion in the equation)		Mean Square Full Equation	Mean Square Reduced Equation
Effect of fitting	X_1	3744.56***	3744.56***
Additional effect of:	X_2	1162.13***	1162.13***
	X_3	1.14	---
	X_2^2	753.42**	754.26**
	X_2^3	1511.63***	1511.84***
	X_2^4	2139.88***	2131.77***
	X_3	---	8.06
	X_3^2	88.88	88.98
	X_3^3	1093.36***	1093.27***
	X_3^4	60.55	---
	X_4	5066.33***	5120.74***
	X_4^2	423.95*	422.95*
	X_4^3	2146.08***	2152.44***
	X_4^4	46.55	---
Effect of all fitted variables		1402.96***	1653.70***
Residual (d.f. = 642-k)†		67.29	67.25

	Coefficient of Determination (Multiple correlation squared) Full Equation	Reduced Equation
R^2	.431	.428
$\overline{R}^2$ (corrected R^2)§	.419	.418

See Table D:1 for footnotes

TABLE D:11

INORGANIC PHOSPHATE: ANALYSES OF VARIANCE SHOWING THE EFFECTS OF REGRESSION EQUATIONS WITH INDEPENDENT VARIABLES THE POWERS OF AMOUNT OF FEED EATEN (X_1), TIME SINCE FEEDING (X_2), TIME SINCE MILKING (X_3) AND TIME OF DAY (X_4)

Source of Variation (Variables in order of their insertion in the equation)		Mean Square Full Equation	 Reduced Equation
Effect of fitting	X_1	22.15	---
Additional effect of:	X_2	9329.94***	9329.94***
	X_3	38.94	---
	X_2^2	450.49*	421.96*
	X_2^3	3.04	---
	X_2^4	19.10	---
	X_3^2	12.48	---
	X_3^3	8.49	---
	X_3^4	14.99	---
	X_4	2741.39***	2439.39***
	X_4^2	507.42*	569.34**
	X_4^3	1018.94***	869.54**
	X_4^4	42.81	---
Effect of all fitted variables		1093.09***	2726.01***
Residual (d.f. = 642-k)†		81.79	81.67

	Coefficient of Determination (Multiple correlation squared)	
R^2	.276	.262
$\overline{R}^2$ (corrected R^2) §	.261	.256

See Table D:1 for footnotes

APPENDIX E

A CONTINUOUS METABOLIC PROFILE OF GRAZING DAIRY CATTLE OVER A ONE YEAR PERIOD

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In New Zealand the feeding of dairy cattle is by the continuous grazing of pasture over the whole year, with comparatively little hand feeding being practised as in Europe. Therefore it was considered that the marked fluctuations in both quality and quantity of feed over which the farmer has little control may effect a metabolic profile more profoundly than in countries where hand feeding is extensively practised.

The use of a metabolic profile has been principally to determine the adequacy of a particular feeding regime [13, 14, 15, 16].

Comparison between lactation groups has made this possible by cancelling between herd differences. In New Zealand between lactation group comparison is not possible because cattle are managed to calve over a short period. Therefore a different approach was necessary for the determination of normal values of the profile in New Zealand dairy cattle.

MATERIALS AND METHODS

To assess how much of the differences between herds were made up of factors which could be determined readily, four herds were sampled at four-weekly intervals for a period of one year. In each case the same animals were followed throughout the whole period wherever possible. In this particular study the factors which comprised the profile were measured over this period and by a statistical method a curve was plotted for each parameter for each of the farms involved.

With the exception of one herd and a few individuals, mainly Jersey cattle were selected for this trial. The exception was a herd of Friesian cattle which supplied milk for Palmerston North city and had a calving pattern largely divided into two peaks referred to as spring and autumn calving groups.

The cattle were grazing pasture during the whole trial, which is the traditional form of feeding management in New Zealand, and although ensilage and hay were fed at times to all cattle, no cereal grain concentrates were used.

The samples were collected under reasonably uniform conditions. In this study the samples were collected in commercially prepared evacuated glass tubes which was different from the original and apparently later work of Payne [13, 16]. For this series of experiments two sets of tubes were used, one without additives for the serum tests and one to which 20 mg potassium oxalate and 25 mg sodium fluoride had been previously added. The samples collected in the latter tubes were used for the haematological assessments and the combined glucose and urea measurements. Because of the volume of material handled with only minimum technical help, it was found not possible to separate clots and serum for twenty-four hours. It was realised that because of this, serum phosphate levels were probably elevated [19].

The tests were done on the blood samples as reported in the original work of Payne *et al.*, [13]. The haemoglobin (N-18a), calcium-inorganic phosphate (N-26a1), total protein-albumin (N-27), and sodium-potassium (N-20b) estimations were carried out using the auto-analyzer N-method file. The glucose-urea method (N-16b) was modified by using saline in which 0.5 % potassium cyanide had been added as the diluent stream. The effect ot the potassium cyanide was to increase sensitivity as described in the micro-glucose method (N-9a). The sample pump tube size was increased to 0.025 inches I.D. to increase the glucose concentration in the sample-reagent stream.

The magnesium estimation was carried out on a Varian Techtron AA5 atomic absorption spectrophotometer. The sample was diluted at the rate of 0.2 ml serum added to 5.0 ml of 1,000 ppm Sr solution. The prepared sample was then burnt in an air/acetylene flame and the absorbence read at 285.2 nm.

The haematocrit was carried out on an International Equipment Limited micro-heamatocrit centrifuge.

A total of nearly 1,800 samples was collected and analysed and the results subjected to a variety of statistical analyses. In this section of the project a statistical package was used to calculate regression coefficients to the fourth power. These were then plotted out for time of year by means of a separate poly-plot programme on an IBM 1620 II computer.

COMMENT

The plots for haemoglobin and haematocrit both showed a pronounced seasonal variation. This is reflected in the curves plotted from the data and several points are significant. First, all farms showed the same trend. Second, there was a considerable difference between each farm. Third, the low point for each farm appeared to be autumn at which time pasture protein in New Zealand is very high [7]. This latter point ruled out any association between protein intake and haemoglobin levels [14, 15, 20] unless there was a three -month delay in effect, which was unlikely. The cause of the summer rise was in agreement with work already published, [4, 8, 9, 10, 17], and was a direct temperature relationship; the winter rise on the other hand cannot be adequately explained.

The serum potassium level did not appear to show any direct seasonal effect; rises and falls on the different farms were superimposed. Paradoxically, serum sodium appeared to show a possible seasonal trend from a high level in summer to a low level in autumn. This probably reflected some degree of water deprivation during the hot summer months.

Plasma glucose produced no definite seasonal trend but appeared to be more closely related to feed and management. In particular the No. 3 Unit was overstocked and the cattle were at times on a lower level of nutrition than was necessary for maintenance and full production. This was reflected by a marked fall in plasma glucose during this period. The feeding of ensilage failed to correct this low plasma glucose level, but hay feeding brought about a quick return to normal levels. This effect has been reported previously [2, 3, 16, 12, 13, 14, 15, 11].

A distinct cyclical change was observed in the level of plasma urea nitrogen which was directly related to the protein content of the pasture as plotted from the figures of other workers [7]. The high urea level coincides with the high protein of the autumn pasture.

Serum inorganic phosphate showed a distinct rise with the time of year, reaching a peak in late autumn. A peak at this time of year has been well documented [18, 15, 1] and is a reflection of pasture phosphate levels. There are no measurements of pasture phosphate according to season in New Zealand but there is no reason why the New Zealand herbage should not follow the same seasonal trends as found in South Africa [1].

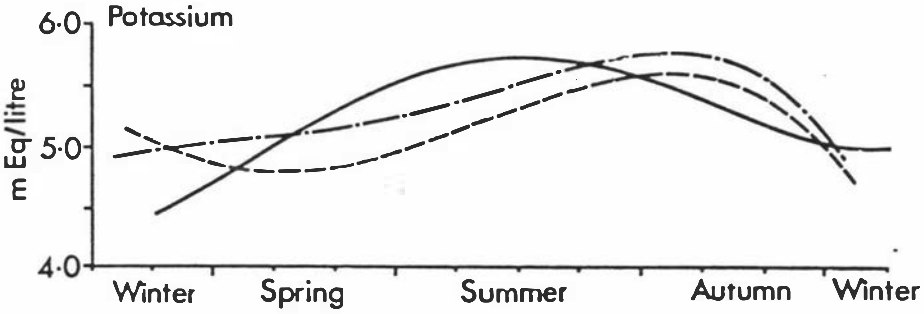
The change in serum calcium appeared similar to but even more marked than the serum inorganic phosphate level and several workers have reported this effect [18, 5, 6]. It may have been related to a higher calcium level in the diet but this seems unlikely in view of the good calcium homeostasis. Hewitt [6] found this effect to be more related to time of year than stage of lactation, so this is probably a genuine seasonal change of unknown cause.

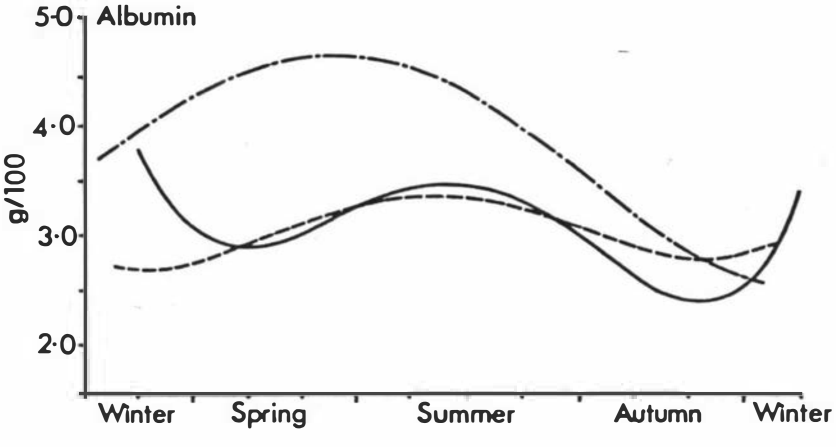
There was no consistent change in the serum magnesium level.

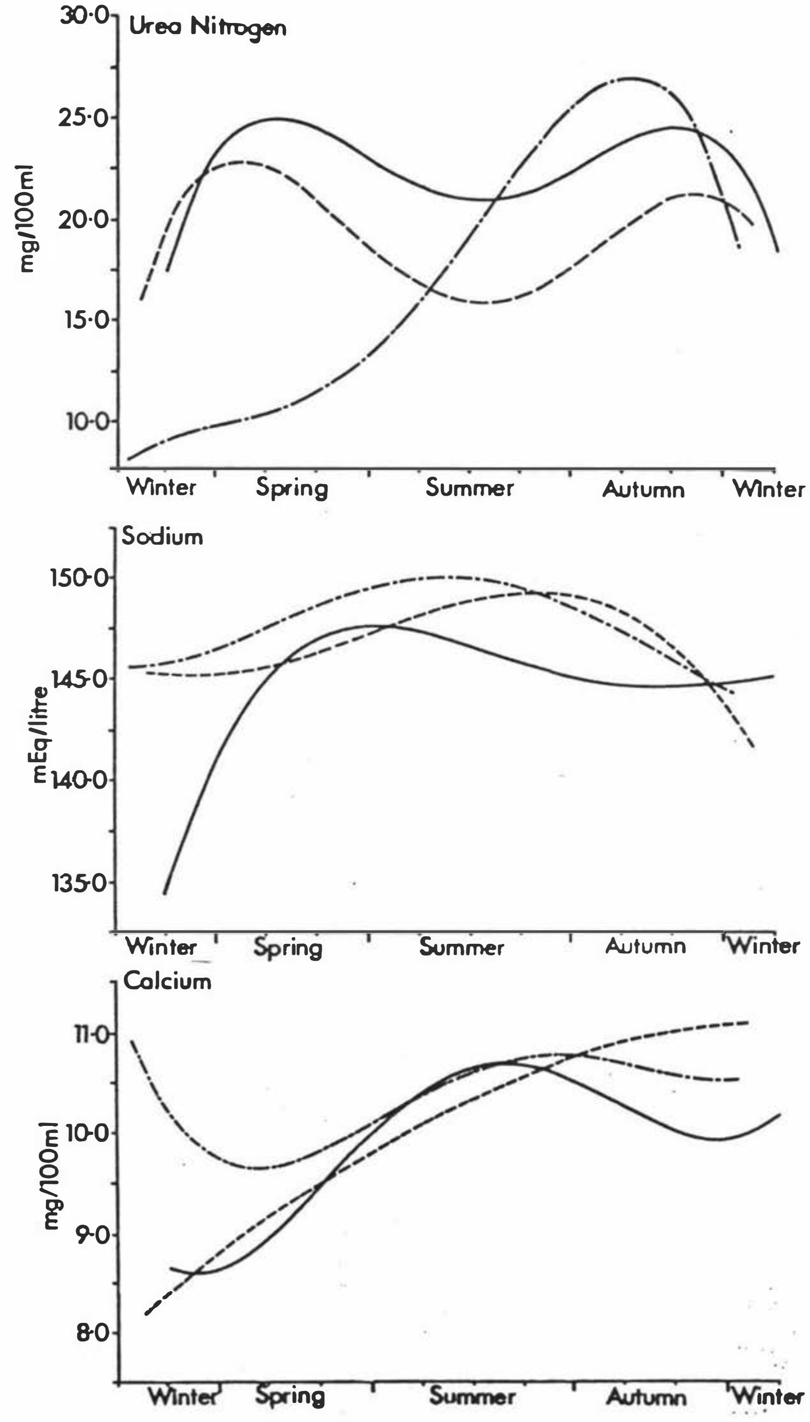
Payne and co-workers [13, 14, 15] reported that serum protein and more particularly serum albumin followed feed protein levels closely. In this study the serum total protein and albumin showed slight changes which in some cases appeared to be a similar curve to haemoglobin and not to follow pasture protein levels. Therefore it is concluded that other factors such as pregnancy and Vitamin A intake must have influenced serum protein levels and serum albumin levels during the course of the year. Further work is needed to elucidate these differences.

CONCLUSIONS

Distinct changes occur in some of the metabolic profile parameters over the course of a twelve-month period. The factors causing these changes may be either climatic as in the case of haemoglobin, haematocrit and sodium or indirectly climatic, for example urea, glucose and inorganic phosphate. Other changes are mediated by unknown factors as shown by calcium, total protein and albumin while further cases showed no distinct seasonal change, for example, magnesium and potassium. These trends were present on all farms but differed in the degrees of change.






Urea Nitrogen
30·0
25·0
20·0
15·0
10·0
mg/100ml
Winter
Spring
Summer
Autumn
Winter
Sodium
150·0
145·0
140·0
135·0
mEq/litre
Winter
Spring
Summer
Autumn
Winter
Calcium
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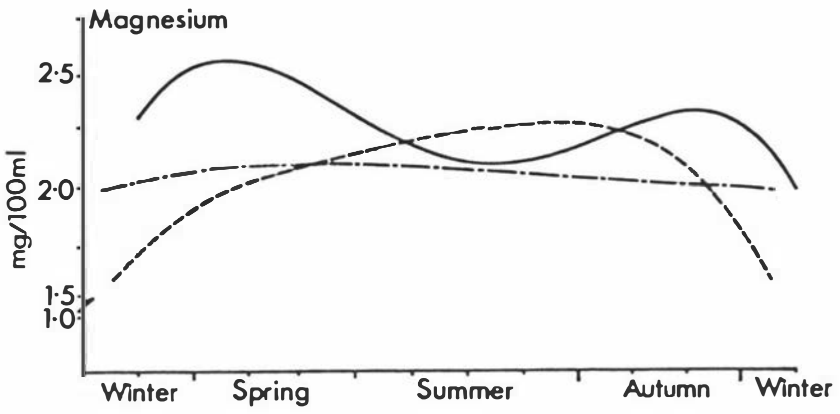
9·0
8·0
mg/100ml
Winter
Spring
Summer
Autumn
Winter


Magnesium
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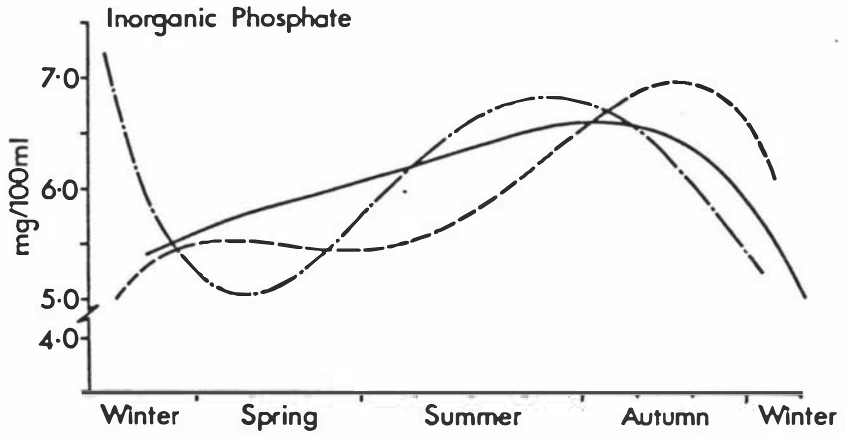
2·0
1·5
1·0
mg/100ml
Winter
Spring
Summer
Autumn
Winter


Inorganic Phosphate
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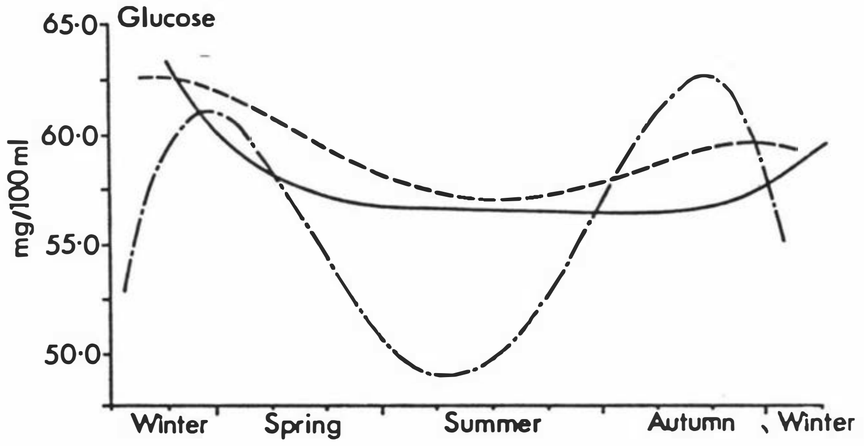
6·0
5·0
4·0
mg/100ml
Winter
Spring
Summer
Autumn
Winter


Glucose
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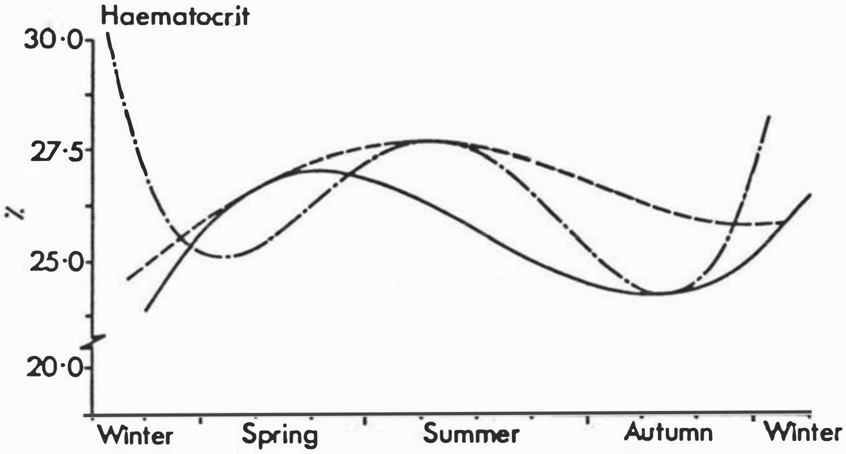
55·0
50·0
mg/100ml
Winter
Spring
Summer
Autumn
Winter


Haematocrit
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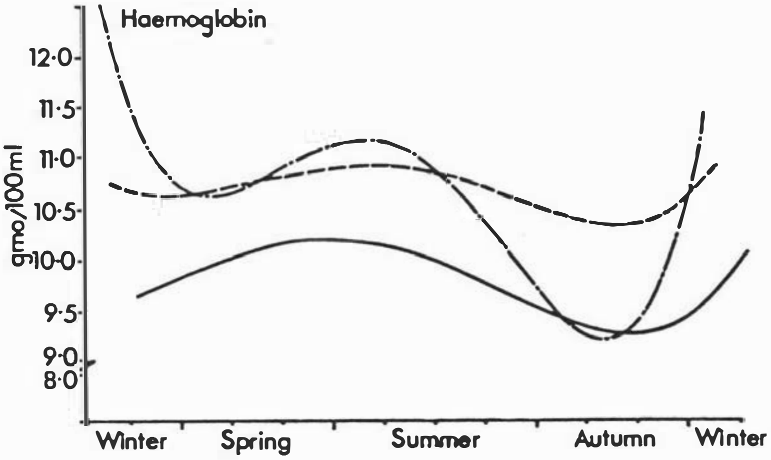
27·5
%
25·0
20·0
Winter
Spring
Summer
Autumn
Winter


Haemoglobin
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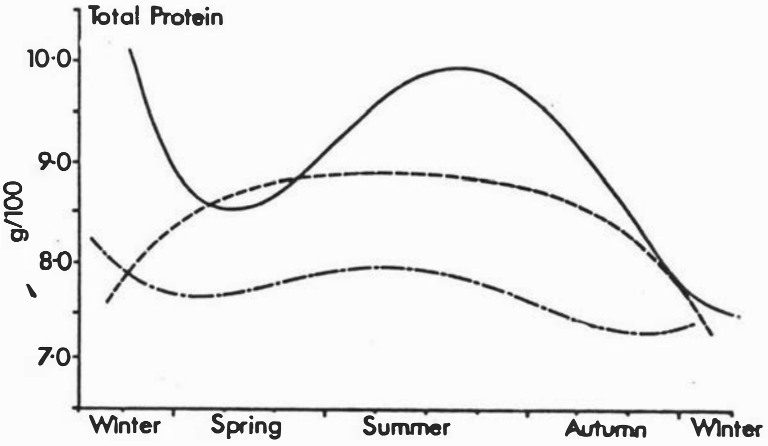
11·5
11·0
10·5
10·0
9·5
9·0
8·0
gms/100ml
Winter
Spring
Summer
Autumn
Winter


Total Protein
10·0
9·0
8·0
7·0
g/100
Winter
Spring
Summer
Autumn
Winter

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RÉSUMÉ

UN PROFIL MÉTABOLIQUE CONTINU DE BOVINS LAITIERS AU PATURAGE SUR UNE PÉRIODE D'UN AN. M. MERRALL.

En Nouvelle-Zélande, l'alimentation du bétail laitier passe par un pâturage permanent des prairies sur toute l'année, avec comparativement peu d'alimentation manuelle comme en Europe.

Donc il a été estimé que les fluctuations marquées à la fois en qualité et en quantité d'aliment, sur lesquelles l'éleveur a peu de contrôle, peuvent affecter un profil métabolique plus profondément que dans les pays où l'alimentation manuelle est couramment pratiquée.

Dans cette étude, des animaux individualisés ont été soumis à l'analyse sanguine dans 4 troupeaux à intervalle de 4 semaines dans l'année. L'échantillonnage a été établi de façon à donner des informations sur la nature et l'étendue des changements physiologiques qui pouvaient être attribués à la nutrition courante, à la saison, au stade de lactation, à la gestation et à l'âge de l'animal.

Des changements sont détectés dans certains des paramétres mesurés. Ceux-ci comprennent les teneurs en Hb, hématocrite, urée plasmatique, Ca, Na, phosphate inorg, sériques, glucose plasmatique, protéines totales et albumine sériques. Aucun changement significatif n'a été détecté dans le magnésium et le potassium sériques.

Il est estimé que le contrôle des profils métaboliques, bien qu'ils soient encore au stade expérimental, est extrêmement prometteur comme guide dans l'appréciation des aliments disponibles chez les bovins laitiers.

ABSTRACT

A CONTINUOUS METABOLIC PROFILE OF GRAZING DAIRY CATTLE OVER A ONE YEAR PERIOD. M. MERRALL.

In New Zealand the feeding of dairy cattle is by the continous grazing of pasture over the whole year, with comparatively little hand feeding being practised as in Europe. Therefore it was considered that the marked fluctuations in both quality and quantity of feed, over which the farmer has little control, may affect a metabolic profile more profoundly than in countries where hand feeding is extensively practised.

In this study individual animals were monitored in four herds at regular four-weekly periods over the year. The sampling was designed to give information on the nature and extent of physiological changes which could be attributed to current nutrition, season, state of lactation, pregnancy and age of the animal.

Changes were detected in some of the parameters measured. These included haemoglobin levels, PCV, plasma urea, serum calcium, serum sodium, serum inorganic phosphate, plasma glucose, total serum protein and serum albumin levels. No significant changes were detected in serum magnesium and serum potassium. In some cases the levels of metabolites varied randomly. This variation cannot be explained at present.

It is considered that the measurement of metabolic profiles, while still in the experimental stage, holds considerable promise as a guide to the suitability of the available feed in dairy cattle.