The Metabolic Profile of Grazing Dairy Cattle

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The term "metabolic profile" was first used by Payne and co-workers (15) to describe a test which was being used by them to assess the potential level of "production diseases" within a dairy herd. Production disease itself was defined as an imbalance in the input-throughput-output of a particular substance in the production by a dairy cow of, say, milk. They attempted to obtain an assessment of production disease by measuring haemoglobin, haematocrit, sodium, potassium, glucose, urea nitrogen, calcium, inorganic phosphate, total protein albumin, globulin and magnesium on a single blood sample. The sample was collected and a portion treated with a glucolytic inhibitor to stabilise glucose levels. The remainder was allowed to clot and the estimations were performed on the serum collected from it. In the paper (15) it was claimed that the test had been used to solve a number of problems in production or management which had not been solved by a more conservative approach.

These workers subsequently used the method on a wider range of herds and wider afield in the southern half of England (16,17). As a result of this work, adjustments were made to the mean and standard deviations about the mean for each parameter, since these were the basis of the interpretation of the test. The manner in which the test was carried out, however, remained very much the same.

Before comparing the results of the study reported here with the U.K. findings, a number of points concerning the different components of the profile deserve comment.

Protein: The values for haemoglobin, albumin and urea are claimed to give a good estimate of the adequacy of protein levels in the diet (15). Haemoglobin is a protein-based compound which may be affected by a long term dietary deficiency of protein but may also be influenced by a wide variety of non-nutritional factors (13). Albumin is one of the protein fractions of the blood plasma. Produced by the liver, it has a relatively short half life (14) and is influenced by shortages of intake (13). Mobilisation of other body proteins can reduce the influence of diet on the albumin level but a fall generally occurs if the diet is inadequate. Albumin can also be lowered by increased loss from the bloodstream (8) but generally this is part of a disease syndrome and is unlikely to show in the profile unless clinically obvious. Urea nitrogen is proportional to the rumen ammonia level which is itself generally proportional to the level of soluble protein in the diet (23). However, urea is also influenced by a number of factors other than the protein content of the diet (4). In the interpretation of these and other elements of the profile it should be remembered that any of the three values can vary from each other for a number of reasons; there are also marked daily fluctuations. It is preferable therefore to give due regard to repeat samples at intervals of 24 hours or longer; especially when at least two of the parameters are outside the normal range.

Energy: The use of the profile as a measure of energy intake is less well defined. Because of the obligatory brain requirement for glucose (11), there is a relatively rigid homeostassis and a cow has to be in a prolonged moderately severe negative energy balance before hypoglycaemia can result. While measurement of glucose is therefore unsatisfactory as a measure of energy in the diet there is no doubt that it should remain included in the profile because if results indicate that the majority of the herd has a low blood glucose, then a problem certainly exists. There are other factors, such as body weight and milk production which give a better indication of whether sufficient energy is being supplied to the cow.

Sodium and potassium: The inclusion of potassium in the profile of grazing dairy cattle is unnecessary as the forage is very rich in potash (22) and excess voided in large quantities in urine. Sodium is more important and during the period of peak lactation, or when cattle are grazing a pasture of low water content, it is possible that the diet may contain inadequate sodium (18). Under these circumstances, faecal and salivary sodium is reduced markedly, urinary sodium is reduced and finally there is a slight drop in serum sodium (2). If accurate information is required of sodium status, saliva is the best sample. The question remains however as to the point at which inadequate sodium limits milk production. It may well be that a fall in serum sodium precedes any depressing effect of inadequate sodium on milk production; more information is necessary to answer this question.

Calcium and inorganic phosphate: Although serum calcium levels are strictly controlled by the homeostatic mechanism, minor day-to-day changes are recorded. Should these changes become significant on a herd basis, obvious clinical signs are likely. The adequacy of inorganic phosphate is difficult to assess. Certainly in conditions of nutritional inadequacy, there is a fall in serum inorganic phosphate (1). However, there is also evidence that this response occurs only at an advanced phase of phosphorus depletion (6,7) and that bone biopsy is the best sample for the evaluation of phosphate status. No information at present exists as to whether a low phosphorus intake is production limiting before it becomes evident as a fall in serum inorganic phosphate.

Magnesium: More information exists about the effects of a low serum magnesium level. As well as knowing that serum magnesium levels of 1.0 mg/100 ml may be associated with clinical hypomagnesaemia, we now have evidence to suggest that a level below 1.5 mg/100 ml is production limiting. In the homeostatic mechanisms associated with magnesium, this seems to be the level below which urinary excretion appears to almost cease. However, although urinary spill-over of magnesium occurs above a level of 1.5 mg/100 ml (20,21), the blood level of this element does increase when amounts above requirements are available in the diet and 2.2 mg/100 ml is regarded as normal under New Zealand conditions. Serum magnesium levels can yield vital information and thus their inclusion in a metabolic profile is worthwhile.

Others: Since the original three papers (15,16,17) the haematocrit has been discarded because of the inability to automate the test and the fact the haemoglobin estimation yields the same information. Copper has been added because parts of Britain are copper deficient and it is felt that marginal areas would be better delineated. At this stage there appears to be no work which specifies a level of serum copper below which productivity is depressed.

Total iron binding capacity and serum iron have also been included because a number of herds are recorded with anaemia and lower productivity. These measurements are designed to assess whether the anaemia is associated with inadequate iron, inadequate protein, "lactational stress" or some other unidentified factor. So far results have not been conclusive although there are indications that a fall in total iron binding capacity could account for some degree of the seasonal anaemia (12) that is observed.

Materials and Methods

The cattle selected for the trial were all part of various dairy herds attached to Massey University and were run under a year-round grassland farming system. They were selected to give a spread of age, calving date and past production performance. A particular problem was posed by the management practice of seasonal calving where virtually all the cattle calve over a short period at the same time each year. This was overcome by selecting one group of animals from the No. 1 dairy unit; this is a Friesian herd supplying milk on daily quota for Palmerston North city. The herd therefore calves at two separate times of the year with the autumn calving group calving five months ahead of the spring calving group. Thirty-one cattle were selected from each group.

The No. 2 unit is a mixed breed herd composed entirely of identical twins and using the same criteria chosen for the No. 1 dairy unit; 18 twin pairs were selected. The No. 3 dairy unit was a Jersey herd divided into four differing management groups; 14 cattle were selected from each of the four groups.

Two samples were taken from each cow into commercially prepared blood sampling tubes. The first was a plain tube to allow clotting for the serum estimations and the second was a tube for the haemotological and glucose estimations containing sodium fluoride and potassium oxalate. Sampling was carried out at four-week intervals throughout the year.

The haematocrit was performed as a microhaematocrit determination. The magnesium estimation was carried out on a Varian Techtron AA5 atomic absorption spectrophotometer. All other estimations were carried out on an Autoanalyser® using the appropriate N- method® file procedure.

Findings

Haemoglobin and haematocrit: Both haemoglobin and haematocrit show a marked difference to the U.K. figures (Table 1). These are also lower figures than the mean figures accepted by the local Animal Health Laboratory. There is probably a management factor applied to the Massey Dairy Farms which has a depressant effect on these values. However, since the Animal Health Laboratory figure is also lower than the U.K. figure it is probable that New Zealand cattle generally tend to have lower haemoglobin levels than their U.K. counterparts. No specific reason can be given at this stage for these differences although they do highlight the need for "local" means. Local means however need to be treated with caution since it is possible, particularly with minerals, that an entire population in an area could be marginally deficient.

The seasonal changes displayed by these parameters in New Zealand (Figs. 1 and 2) show a rise in early spring leading to a peak in late spring to early summer. A fall was then recorded to a low point in mid autumn with a rise again as winter started. In the U.K. (15,16,17) a fall is recorded in the indoor winter feeding phase which is followed by a rise as the cattle are turned out to pasture. Scandinavian workers (19) record a rise in January-March equivalent to the rise in winter in this plot. The rise occurred on all three units although the peaks and troughs varied slightly in their timing on the differing units.

Sodium and potassium: The absolute figures (Table 1) for potassium are not very different from the U.K. figures. The seasonal movement here in potassium (Figure 3) is a steady small rise to a peak in late summer and early autumn. The figures for sodium (Table 1) recorded were considerably higher

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and more variable than the U.K. figures. Problems were encountered with the analytical method and multiple repeat testing was not possible because of restrictions on the quantity of serum available. Seasonal plots were therefore not carried out. In a subsequent trial a mean of 140.5 mEq/l for sodium has been recorded though the standard deviation remains high.

Glucose: Glucose estimations were carried out on plasma in this project whereas they were carried out on whole blood in the U.K. Plasma glucose was selected because it was simpler and because the glucose content of the ruminant erythrocyte is negligible (10). The mean from this trial is higher (6%) than the converted U.K. figures, but this may have arisen from the conversion method used to make the comparison (24).

The seasonal changes (Figure 4) are a little difficult to interpret but they do tend to show a fall for all units towards mid summer. The fall coincides with peak lactation and in the No. 2 unit, the rise with the cessation of lactation. The No. 1 unit shows the same pattern but because of the two different calving periods in this herd it was possible to see that there was both a lactational and a seasonal effect on blood glucose levels (Figure 5).

The No. 3 unit shows the greatest change and in this unit the change was referable to the level of nutrition. The stocking intensity was high (1.75 cow/acre) and "drought" conditions prevailed throughout spring and summer. By early February virtually all feed being eaten was conserved fodder in the form of hay or ensilage. Starting approximately mid February the cattle were fed ensilage for one month until supplies ran out and were then fed an equivalent amount in dry matter of hay which was continued until they were dried off two months later. The ensilage produced no response in blood glucose level but the hay produced an almost immediate response, the level falling again when feed was reduced at the cessation of lactation. Body condition lost was quite marked and the fall in blood glucose tended to follow other, more obvious signs of inadequate nutrition.

Urea nitrogen: Protein intake appeared to govern the plasma urea nitrogen level. The plot of pasture protein percentage (Figure 6) was prepared from figures of pasture in the Waikato (9); local figures obtainable showed the same curve but did not extend for the period of the year required. The January rise was a result of a summer rainfall which did not occur during the duration of the profile. The spring and autumn rises in pasture protein resulted in equivalent rises in the urea nitrogen graph (Figure 7). The actual mean value was higher than the U.K. figures because of the excess protein content of N.Z. pasture relative to the cows' requirement. The low level at the start of the plot for the No. 3 unit can only be explained on the basis of an inadequate diet which was reflected by a steady decline in blood glucose level.

Inorganic phosphate: The mean inorganic phosphate level was virtually the same as the U.K. figure (Table 1). With the amount of phosphatic fertiliser being applied in New Zealand, it is unlikely that a deficiency will arise except under special circumstances. The seasonal graph (Figure 8) does tend to show a slow rise to a peak in autumn when according to overseas work pasture phosphate is at its maximum (1).

Calcium: The serum calcium is marginally higher in N.Z. dairy cows than in their U.K. counterparts (Table 1) but there is no authoritative material for comparing the incidence of milk fever between the two countries. There was evidence of a seasonal variation in calcium; the serum level being lowest in the spring (Figure 9). There was also a lactation effect as well as a seasonal effect as illustrated by the separate spring and autumn calving groups (Figure 10). This could be important as a smaller absolute fall in serum calcium would be necessary to precipitate paresis in the spring compared with the autumn. Evidence that such is the case is not borne out by a survey of milk fever incidence in Canada where the incidence was highest in June, August and September (7).

Proteins: The measurements of total protein and albumin were also higher than the U.K. figures (Table 1). This could be due to age differences. Globulins increase with age and in an effort to get maximum spread of ages there were cows up to twelve years old in the experimental groups. In the seasonal plots (Figures 11 and 12), it was difficult to detect any seasonal effect on the total protein. The albumin plot does follow a curve following the estimated pasture protein content by two to four weeks; the changes are therefore probably nutritional in origin.

Magnesium: Magnesium levels in cattle sera have received a lot of attention in N.Z. because of their association with clinical hypomagnesaemia. New Zealand serum levels tend to be lower than a lot of overseas countries. This is supported by the mean value in this trial being lower than the U.K. figure (Table 1). There are a lot of factors which can influence this, such as pasture composition, fertiliser regime and soil composition. A full discussion on the causes of variation in the availability of pasture magnesium is beyond the scope of this paper but the lower mean is a probable indication that, under N.Z. grazing conditions it is a valuable, even essential component of the profile. The seasonal plots (Figure 13) do not show a seasonal variation under the conditions of this trial which is unusual; no clinical hypomagnesaemia, however, was observed. Other trials have revealed no consistent pattern of seasonal variation from one property to another or from one season to another.

Conclusions

The metabolic profile as it stands at the moment is not a valid tool for the diagnosis of nutritional balance on its own. It is useful, however, as part of a wider investigation of dairy cattle nutrition. It is useful for research in the possible selection of

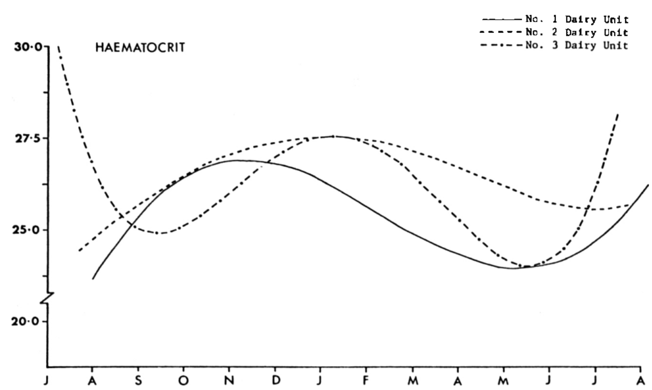

Figure 1. Seasonal changes in the components of the metabolic profile.

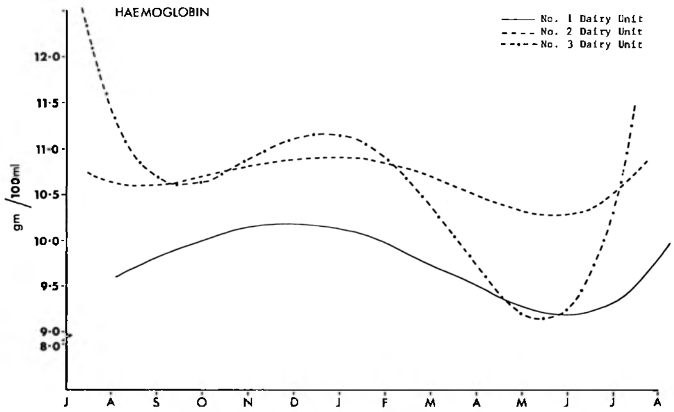

Figure 2. Seasonal changes in the components of the metabolic profile.

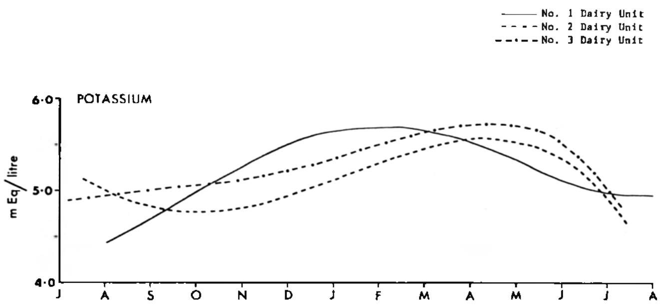

Figure 3. Seasonal changes in the components of the metabolic profile.

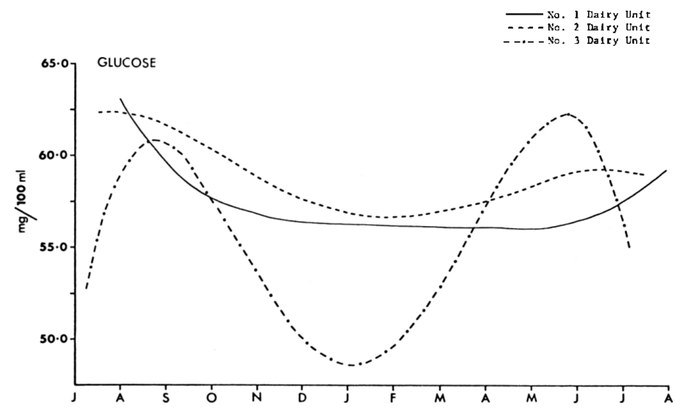

Figure 4. Seasonal changes in the components of the metabolic profile.

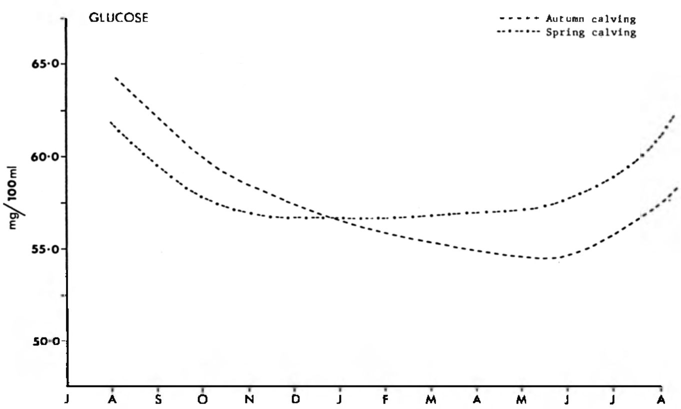

Figure 5. Differences in the seasonal changes of components of the metabolic profile influenced by a different calving time.

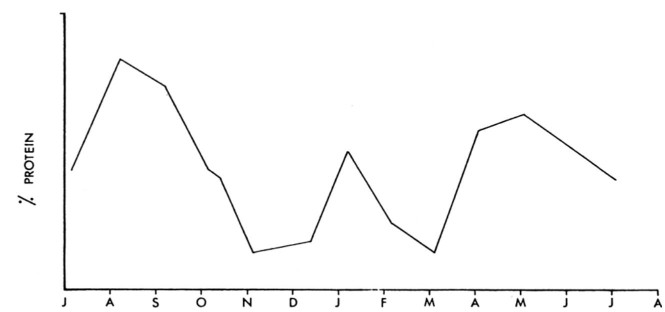

Figure 6. Seasonal changes in the protein content of mixed New Zealand pasture.

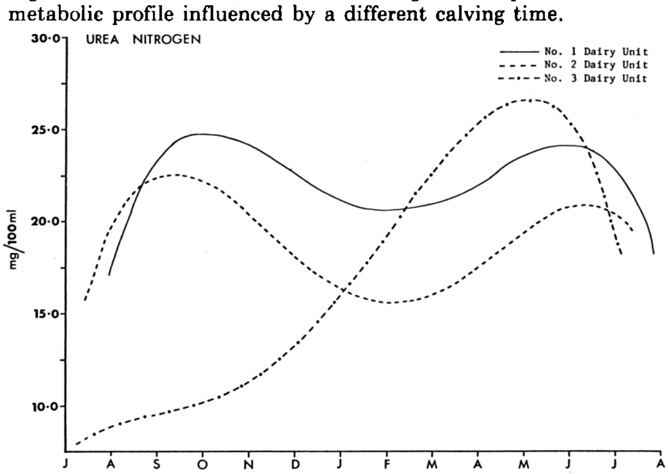

Figure 7. Seasonal changes in the components of the metabolic profile.

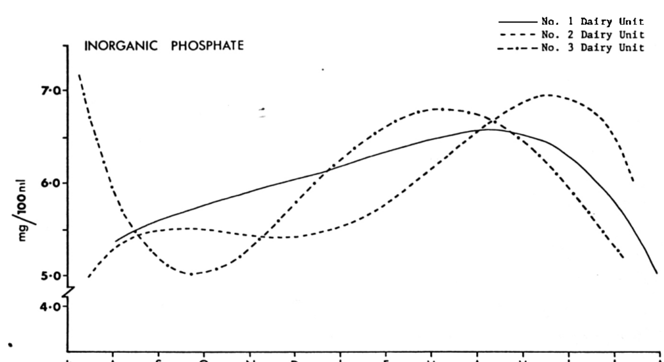

Figure 8. Seasonal changes in the components of the metabolic profile.

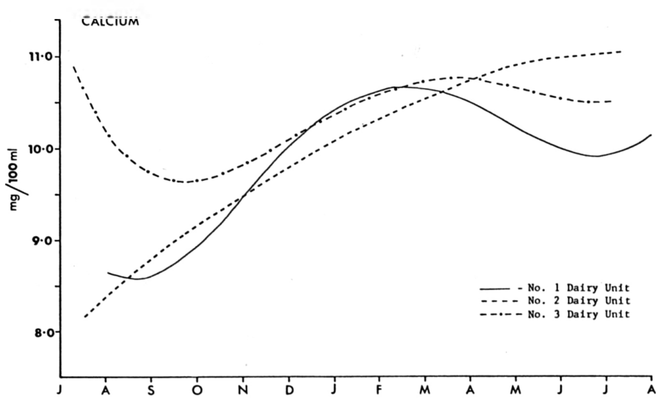

Figure 9. Seasonal changes in the components of the metabolic profile.

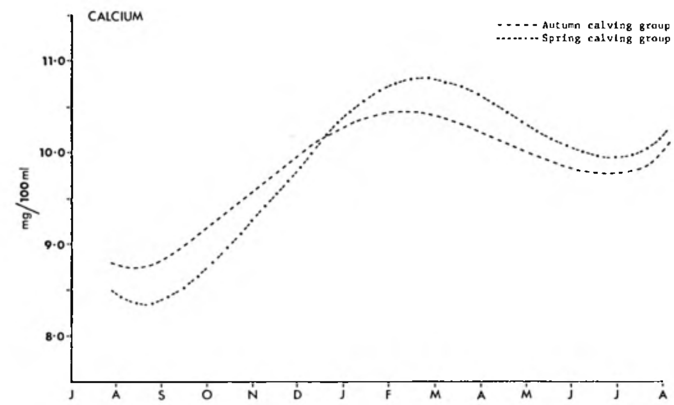

Figure 10. Differences in the seasonal changes of components of the metabolic profile influenced by a different calving time.

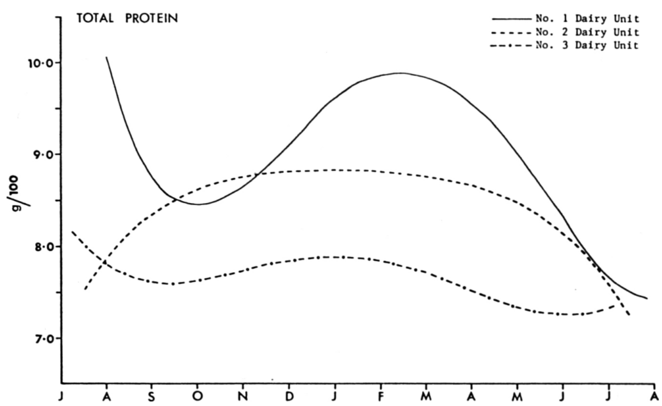

Figure 11. Seasonal changes in the components of the metabolic profile.

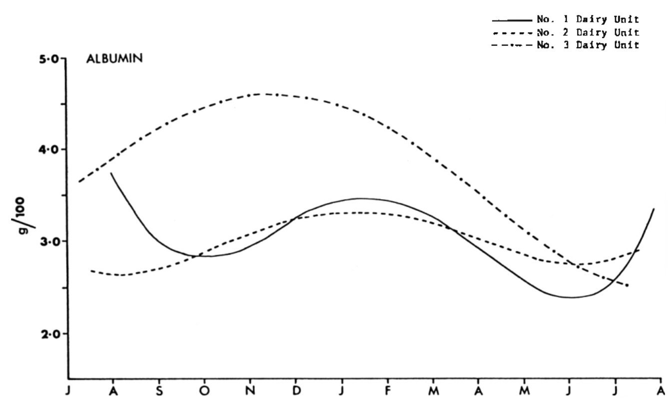

Figure 12. Seasonal changes in the components of the metabolic profile.

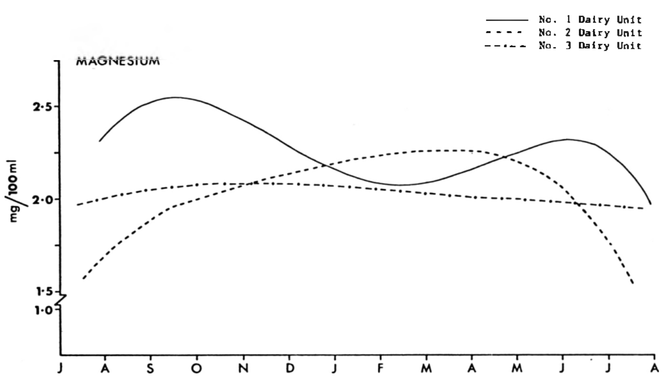

Figure 13. Seasonal changes in the components of the metabolic profile.

Table 1. Means and Standard Deviations from United Kingdom (17) and from the Three Massey Dairy Units

	Results							
	U.K.		No. 1 Unit		No. 2 Unit		No. 3 Unit	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Haemoglobin g/100 ml	12.1	1.0	9.8	1.1	10.6	1.3	10.6	1.4
Haematocrit %	30.2	2.8	25.4	2.8	26.4	2.9	26.4	3.1
Sodium mEq/l	139.7	2.1	144.4	6.2	146.8	5.2	147.5	4.6
Potassium mEq/l	5.0	0.4	4.9	0.6	5.2	0.6	5.1	0.6
Glucose mg/100 ml*	54.0	6.4	57.8	5.9	59.0	6.0	55.6	7.6
Urea nitrogen mg/100 ml	14.4	2.5	22.1	5.5	18.8	5.0	16.7	8.2
Inorganic phosphate mg/100 ml	6.0	0.9	6.0	1.3	5.8	1.3	6.0	1.3
Calcium mg/100 ml	9.5	0.4	9.8	1.3	9.9	1.4	10.4	1.4
Total protein g/100 ml	7.1	0.5	9.1	1.0	8.5	0.8	7.7	0.6
Albumin g/100 ml	3.4	0.3	3.1	0.6	2.9	0.5	3.8	0.9
Magnesium mg/100 ml	2.5	0.2	2.2	0.6	2.0	0.6	2.0	0.7

*The mean and standard deviation figures have been converted from the U.K. figures on whole blood to plasma values (24).

genetically superior animals and for investigations on different types of management systems. It is valuable as an aid in the diagnosis of clinical problems which have not been solved by conventional methods.

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