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THE MAINTENANCE REQUIREMENTS OF NEW ZEALAND DAIRY CATTLE

J. B. HUTTON

Ruakura Animal Research Station, Hamilton

SUMMARY

Results of experiments designed to measure the maintenance needs of pasture-fed dairy cattle are reported.

Herbage intakes were measured for three separate groups of cattle; one consisted of dry cows fed to maintain a constant liveweight, the other two comprised dry and lactating cows, respectively, both of these groups being fed to appetite.

Comparisons involved the calendar period September-January and data were obtained in the 1959-60, 1960-61, 1961-62 dairying seasons. To ensure accurate measurement of intake, all cattle were fed indoors.

The amount of D.O.M. required to maintain constant liveweight was essentially the same as maintenance requirements published in standard feeding tables for mixed concentrate and roughage diets.

Application of least squares analysis to intake and liveweight data from the fully-fed dry cattle gave estimates of maintenance requirements approximately 30% higher than currently accepted values. Comparable values for the lactating cows calculated in a similar way were almost twice those contained in standard feeding tables.

D.O.M. requirements for milk production and liveweight change estimated from these analyses were lower than and similar to the currently accepted values, respectively.

These results have been compared with previously published data and reasons for the present high values for estimated maintenance requirements have been suggested.

It is concluded that, for lactating cows, reasonably precise estimates of D.O.M. intake can be obtained by calculating the regression of the latter on milk yield, body weight raised to the 0.73 power, and liveweight change when each of the independent variables is measured accurately.

MAINTENANCE REQUIREMENTS of farm livestock are generally expressed in terms of energy and protein, but since, in New Zealand, pasture herbage contains an abundance of protein, interest is generally restricted to the energy fraction of the diet. The energy cost of maintenance is simply defined as the number of calories required to maintain the animal in energy equilibrium, and implies that the animal is in carbon and nitrogen balance.

Most of the basic information on the maintenance requirements of farm livestock has been derived from animal calorimetry studies most of which were carried out by Kellner and his associates at Möckern, Armsby and co-workers at Pennsylvania State College, Benedict and Ritzman at New Hampshire, and Möllgaard at Copenhagen. These experiments, together with the practical feeding trials of Haecker, Hill and Forbes in the U.S.A. and Hansson and Frederiksen in Scandinavia, provided much of the data from which both the American, total digestible nutrients (T.D.N.), and European, starch equivalent (S.E.), feeding systems were derived.

In addition to supplying information on the maintenance and production requirements of different classes of livestock, these experiments were designed to determine the extent to which animal requirements could be met by different feedstuffs. The classes of feeding stuffs which most interested these workers were concentrates and, to a lesser extent, roughages, and the number of direct calorimetric determinations carried out on pasture herbage were strictly limited.

Despite the many limitations of tables of feed values and requirements, which have been admirably summarized by Blaxter (1950, 1956), they have proved extremely useful for feeds and systems of feeding employed in Continental countries where rationing and stall feeding of animals is economically essential. Information derived from the original calorimetric studies has been added to by numerous indoor feeding trials in which adequate control of feed intake and animals was possible. Feed requirements have been assessed by statistical procedures such as those employed by Armsby and Moulton (1925), Gaines (1943) and Brody and Proctor (1935), but always there has been available the basic calorimetric information against which these results could be checked.

In New Zealand, the livestock industry is almost entirely dependent upon pasture as a source of feed. In trying to evaluate the quality of pasture in terms of animal response, it is found that very little basic experimental work is available from which to obtain an accurate measure of the quantitative needs of farm animals for maintenance or production from pasture. It has been customary to carry out chemical analyses of herbage samples, to determine herbage digestibilities, and by reference to the National Research Council (1956) tables or those of the Ministry of Agriculture, Fisheries and Food (*Rations for Livestock*, 1960) to calculate T.D.N. or S.E. values. This, together with an assessed herbage dry matter yield, provides a theoretical measure of the potential productivity of pasture herbage. Such a procedure involves the following assumptions:

(1) The net availability of energy from pasture herbage is similar at all levels of intake to that for the concentrate diets of like gross chemical composition from which the standards were derived.

(2) The intake and feed requirements of pasture-fed stock are similar to those which obtained under the experimental conditions in which the standard estimates of feed requirements were derived.

With regard to the first of these points, there is now available considerable evidence to show that, at least in the case of the fattening animal, the proportions of the different short-chain volatile fatty acids produced in the rumen from the breakdown of different feedstuffs affect the net availability of the metabolizable energy. Rumen liquor obtained from pasture-fed ruminants is consistently higher in the proportion of acetic acid and lower in propionic and butyric acids than is the case where animals have been fed on concentrate diets, and Armstrong and Blaxter (1957) have clearly demonstrated that the addition of acetic acid to fattening rations reduces the net availability of the metabolizable energy.

The problem of obtaining information on the relative intakes and requirements of free grazing, pasture-fed cattle and animals stall-fed on concentrates is an extremely difficult one. Dr L. R. Wallace has been actively working at Ruakura for several years on methods for estimating the herbage intakes of free grazing animals. By means of the chromium oxide and nitrogen marker method, he has collected a large amount of information on the digestible organic matter (D.O.M.) intakes of pasture-fed cattle, and in an attempt to estimate the nutrient requirements of these animals subsequently subjected the data to multiple regression analysis. This method of partitioning the variance of D.O.M. intake between the yield of fat-corrected milk (F.C.M.), liveweight raised to the 0.73 power ($L.W.^{0.73}$) and liveweight change (L.W.C.) was essentially the same as that employed by Brody and Proctor (1935) when analysing lactation records obtained from several U.S. experimental station herds. This latter analysis produced coefficients for F.C.M., L.W.$^{0.73}$ and liveweight change which agreed closely with values listed in standard feeding tables. This is rather understandable, since the cows were fed according to recognized feeding systems. On the other hand, the equations developed by Wallace (1956) and presented in his paper to the 7th International Grassland Congress were unusual since the coefficient associated with L.W.$^{0.73}$ was almost double what might have been expected from the information contained in standard feeding tables. The interpretation placed on this large coefficient was that the maintenance requirements of pasture-fed, lactating dairy cattle under conditions of free grazing were very much larger than for similar animals stall-fed on a concentrate ration. The data from which Wallace derived his equation have subsequently been criticized by Corbett (1960), Greenhalgh and Corbett (1960), Minson and Kemp (1961) and Corbett (1961). All of these workers point to seasonal biases which exist in the estimation of herbage digestibilities from faecal nitrogen, and suggest that these will cause overestimation of intakes and will probably account for the high maintenance estimate.

In reply to these criticisms, Wallace (1961) presented some results of more recent pasture feeding trials carried out at Ruakura. In all this work feed intakes had been measured indoors, and consequently the major criticism previously raised could not be applied to this particular case. Analysis of these results showed that the coefficient associated with L.W.$^{0.73}$, while lower than the comparable value previously published, yielded an estimate for maintenance which was approximately 30 to 40% above accepted standards.

Corbett (1961), while apparently unaware of this work, recently presented a paper in which he repeated his criticism of Wallace's earlier work and proposed an alternative equation which he had derived from the results of outdoor grazing trials and which gave an estimate of the maintenance requirement of lactating dairy cattle which was consistent with values provided in the standard feeding tables.

In view of the conflicting nature of these various results it would seem appropriate at this stage to present some additional data which have been obtained in feeding trials with dairy cattle at No. 5 Dairy, Ruakura, since these may help to clarify the problem.

METHODS

Trial 1: Estimation of the Maintenance Requirement of Dry Cattle Where Change in Liveweight is Minimal

Consider the first and simplest of these three trials. This has been concerned with measuring the quantities of D.O.M. from fresh pasture which are required to maintain non-lactating dairy cattle at constant weight during a complete dairying season. Without the aid of animal calorimeters, this represents the only way in which maintenance requirements comparable with those listed in overseas feeding tables can be assessed for pasture herbage grown under New Zealand conditions.

For this purpose 12 non-lactating, Jersey, crossbred cattle, consisting of two 2-year-old, three 3-year-old and seven mature cows, ranging in body weight from 530 lb to 1,001 lb, and in body condition from moderately fat to moderately thin, have been used. These cattle have been fed sufficient fresh pasture each day to maintain their mean weekly body weights constant. This trial was initiated in September, 1961, and is still in progress. The part of this trial which will be dealt with in the present paper, however, covers the period of 15 weeks from September 21, 1961, to January 4, 1962.

Mean body weights of individual cows recorded during the week immediately before the trial commenced were accepted as the values to be maintained. Animals were weighed at the same time each day and the amounts of pasture required to maintain body weight constant were then adjusted according to the measured liveweight change. All animals were fed in stalls, receiving their daily ration usually as one feed. On completion of this they were either muzzled and turned out on to a bare paddock or housed in an open barn when it became imperative to reduce depreciation of the muzzles. As a result, during most of the section of the trial which will be considered here, cows restricted to maintenance were indoors for approximately 6 hours each day, and exposed to environmental conditions comparable with those experienced by grazing cattle for the remaining 18 hours.

To calculate the digestibility of the herbage consumed, individual total faeces outputs from three of the cows were determined each week. These groups of three cows remained on digestibility trial for three successive weeks, after which they were replaced by a further three animals from the total group of twelve. Faeces were collected in bags especially designed for the purpose by J. W. Hughes of the nutrition section, and urine contamination of faeces was prevented by the use of urinary catheters. Unfortunately, the development of this equipment was delayed, and it was not possible to use it until approximately half-way through the experimental period. In calculating D.O.M. intakes during the first eight weeks it was therefore found necessary to use the digestibility data derived from a second group of experimental animals which were being fed the same pasture herbage. As will be seen later, this adjustment had very little effect on the general nature of the results.

TRIAL 2: ESTIMATION OF THE MAINTENANCE REQUIREMENT OF FULLY-FED DRY CATTLE UNDER CONDITIONS OF FATTENING

It is clearly recognized that, in addition to its effect on feed digestibility, plane of nutrition also markedly influences the net availability of metabolizable energy. It was therefore considered desirable to compare the estimated maintenance requirements of pasture-fed animals making no weight gains with estimates obtained for essentially similar animals under conditions of maximum intake. Data for fully-fed dry cows derived from a series of comparative intake trials were therefore analysed for the same calendar period of 15 weeks as was considered for the cows on restricted intake. This information had been collected during the 1960-61 and 1961-62 seasons primarily for obtaining a measure of the effect of lactation, within identical-twin sets, on levels of intake and feed utilization under conditions of full-feeding. Data for 13 sets of identical twins were available from both seasons. Those relating to the lactating members will be considered in connection with Trial 3.

Of the 13 dry cows, two were 2-year-old, four were 3-year-old and the remaining seven were mature animals. The mean liveweight of these cattle within one week of their twin mate's date of calving was 755 lb, compared with 760 lb for the lactating twin members. By mid-September, however, when it became possible to start the present comparison, the mean value had increased to 845 lb. At this stage the range in liveweights for individual animals was 531 lb to 1,015 lb.

The same feed was supplied, and the same system of feeding practised for fully-fed dry and milking cows. Fresh pasture was cut once daily, carted indoors, sampled and weighed usually into three main portions for each cow, to provide her feed requirements during the subsequent 24 hours. Feed which was weighed but not immediately required was stored in 20 gal milk cans until needed. The cattle were stall-fed at 5 a.m., 10 a.m. and 4 p.m. and, when required, supplementary amounts of feed were provided. This meant that individual cows could receive 4 to 5 feeds per 24 hours. This system of feeding determined that all cows, except those on digestibility trials, spent approximately 12 of the 24 hours indoors. The remaining period was spent outside, when the cattle were muzzled and allowed access to a bare paddock adjacent to the dairy. Each morning the feed refusals were weighed and sampled, and from these data intakes for the previous 24 hours were assessed. This information was used to compute the current day's requirements and an allowance for refusals of approximately 15% of the green material eaten was generally made.

To determine the digestibility of the herbage, a continuous series of trials was run in which groups of three of the fully-fed dry cows were placed in the metabolism stalls, to provide data on total faeces and urine outputs. These groups remained in the metabolism stalls for two weeks, and were then replaced by a second group, which provided data for the alternate fortnights. For the weeks that cows were not on metabolism trial, D.O.M. intakes were calculated by applying the mean digestibility coefficients, derived from cows on trial at that stage, to the measured O.M. intakes.

Trial 3: Estimation of the Maintenance Requirement of Milking Cows Fully-fed on Pasture Herbage

The third group of cattle for which detailed intake and output information had been obtained consisted of 23 stall-fed lactating Jersey crossbred cows. Thirteen of these were used in experiments in the 1960-61 and 1961-62 dairying seasons and, as indicated in the previous section, were the twin mates of the fully-fed dry cattle described there. In addition, data obtained from ten cows during the 1959-60 season were also included.

Wallace (1961) pointed out that 50% of the animals which provided the intake and output data used by him had various degrees of restriction imposed on their intakes. Because of the importance of level of intake on feed utilization, and since conditions of free grazing impose virtually no restrictions on intake for much of the year, it was considered desirable to estimate feed requirements for milking cattle under conditions of full-feeding. Consequently, all of the results considered in this section refer to animals which were allowed to eat sufficient pasture dry matter to satisfy their appetites.

To render this information comparable with that obtained from both groups of dry cattle, consideration of this has been confined to the same 15 calendar weeks.

The feed and method of feeding used for the milking cows was the same as described for the fully-fed dry cattle. Herbage digestibilities were determined in exactly the same way, except that lactating cows were used in the metabolism stalls. The cows were milked twice daily at 10- and 14-hour intervals, the same machine being used for cows in and out of the metabolism stalls. Samples of milk were taken at each milking and composited for three- and four-day periods before being analyzed for fat percentage by the Gerber method. Total fat-corrected milk was estimated by weeks for individual cows.

In addition to the thirteen milking cows whose age composition was as for the fully-fed dry cattle, the remaining ten animals consisted of four 2-year-old, three 3-year-old and three mature cows. The mean body weight for the full group of 23 cows was 760 lb for the first week after calving, but had fallen to 718 lb by the start of the present trial period. At this stage the range in body weights was 534 lb to 992 lb.

The intervals from time of calving to the start of the present trial period were 11 weeks, 12 weeks and 7 weeks for cows in the 1959-60, 1960-61 and 1961-62 seasons respectively. The mean F.C.M. yield at this stage was 35.1 lb/cow/day and the production range covered was 17.2 lb to 49.2 lb for individual cows.

Features Common to the Three Trials

In addition to similarities already mentioned, the following features were common to all:

(1) Herbage was supplied continuously from the same pastures both within and between seasons. Species present were short-rotation and perennial ryegrasses, white clover, some cocksfoot, Yorkshire fog, paspalum and various weeds.

(2) Dry matter intakes and the amount of faeces dry matter produced by each cow were obtained by weighing all feed offered and refused, and the total quantity of faeces voided. Estimates of dry matter percentage obtained by drying appropriate samples for 24 hours at 100° C were then applied to these.

(3) Organic matter intakes and faecal outputs were calculated using ash values obtained after samples of feed and faeces had been subjected to bomb calorimetry.

(4) All cattle were weighed each day and mean liveweights during successive weeks were averages of the daily values. Weight changes for individual weeks were obtained by halving the difference between the mean values of the preceding and succeeding weeks. The overall weight change was estimated by averaging the weights obtained in the week immediately before and after the days on which the trial commenced and subtracting this from a value similarly determined at the end of the trial.

(5) Feed intake, faeces output, and hence herbage digestibility, were determined for periods of one week.

(6) In the analysis of the data, the comparisons which have been made relate almost entirely to data derived from the full 15-week period.

RESULTS

Trial 1

Figure 1 shows the week-to-week changes in herbage dry matter required to maintain these 12 cows at constant weight. On average it appears that approximately 8 lb of dry matter has been needed for cows averaging 744 lb liveweight, and the digestibility data contained in Fig. 2 provide a measure of the quality of the herbage. A steady decline in herbage digestibility occurs between spring and mid-summer and, between November and January, a measure is obtained of the effect of plane of nutrition on herbage digestibility. The violent fluctuations associated with data from the maintenance group are due to the inevitable carry-over effects of variations in gut fill which are associated with this system of feeding.

Figure 3 provides a measure of the success achieved in maintaining a group of cows varying in both size and condition at constant weight. Mean weekly liveweights at no stage varied by more than 2½ lb from the mean.

Figure 4 records the mean daily D.O.M. intakes of these restricted cattle for each of the 15 weeks. By simple regression analysis the relationship between D.O.M. intake and L.W.$^{0.73}$ was calculated. This regression passed through the origin and was of the form D.O.M. (lb/cow/day) = 0.048 L.W.$^{0.73}$. The maintenance requirement calculated for a 1,000 lb cow from

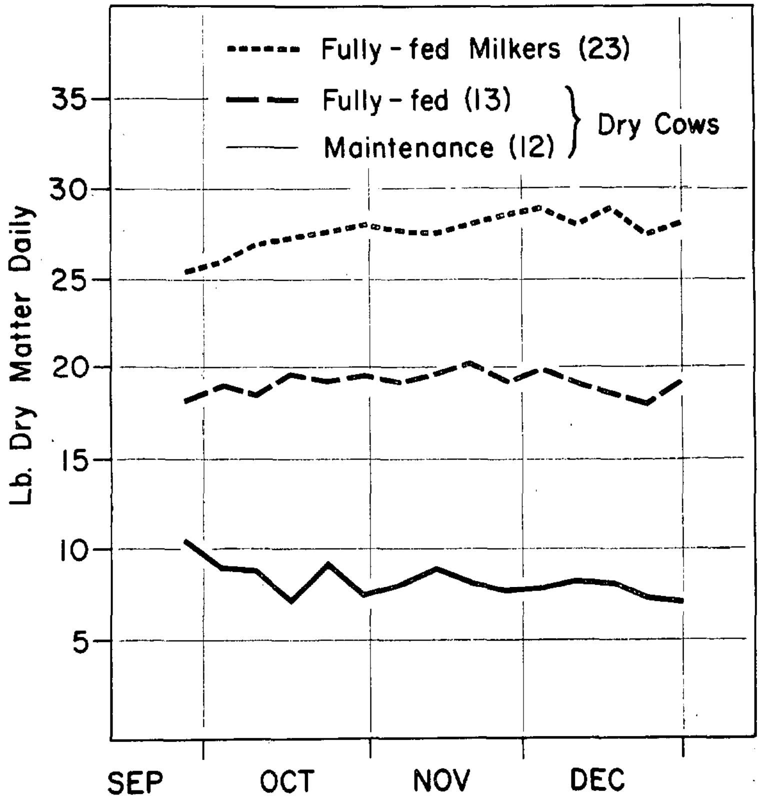

Fig. 1: Mean daily dry matter intake (lb) of pasture-fed cows. 1959-1962.

this coefficient is equal to 7.4 lb D.O.M./day. If 1 lb D.O.M. is accepted as equivalent to 0.92 lb S.E. and 1.04 lb T.D.N., this represents a maintenance requirement calculated in these terms of 6.8 lb and 7.7 lb respectively These figures agree closely with those published for cows of this size in *Rations for Livestock* (1960) (6.5 lb S.E.) and in the National Research Council's (1956) tables (7.0 lb T.D.N.) . This result may be considered in line with the findings of Armstrong *et al.* (1957), who showed with sheep that, when the energy of mixtures of steam-volatile fatty acids is used to prevent energy loss from the tissues, the composition of the mixture has very little effect, and the efficiency of utilization is high.

A further point of interest arises as a result of the trend in the D.O.M. intake of the maintenance fed cattle shown in Fig. 4.

It will be noted that there appears to be a steady fall in the requirement of D.O.M. from September to January, even although body weight is maintained constant. This possibly indicates a change in body composition in response to the restricted feed intake and the conversion of fat reserves to protein, with a consequent reduction in the energy cost of maintenance. If this is in fact happening, it would be in accord with the findings of Carroll *et al.* (1961) who found with mature rats fed for prolonged periods on a ration sufficient to maintain body weight that the proportions of flesh and ash increased and that of fat decreased as the trial progressed. However, regular subjective assessments which have been made of the body condition of the 12 maintenance cows have failed to show any change in degree of fatness.

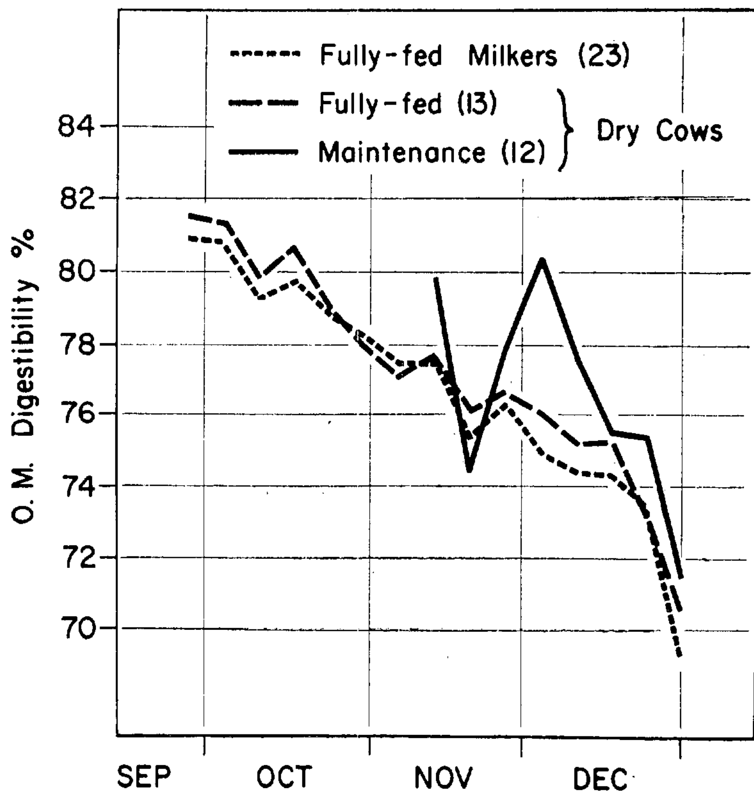

Fig. 2: Mean herbage digestibility (organic matter basis). 1959-1962.

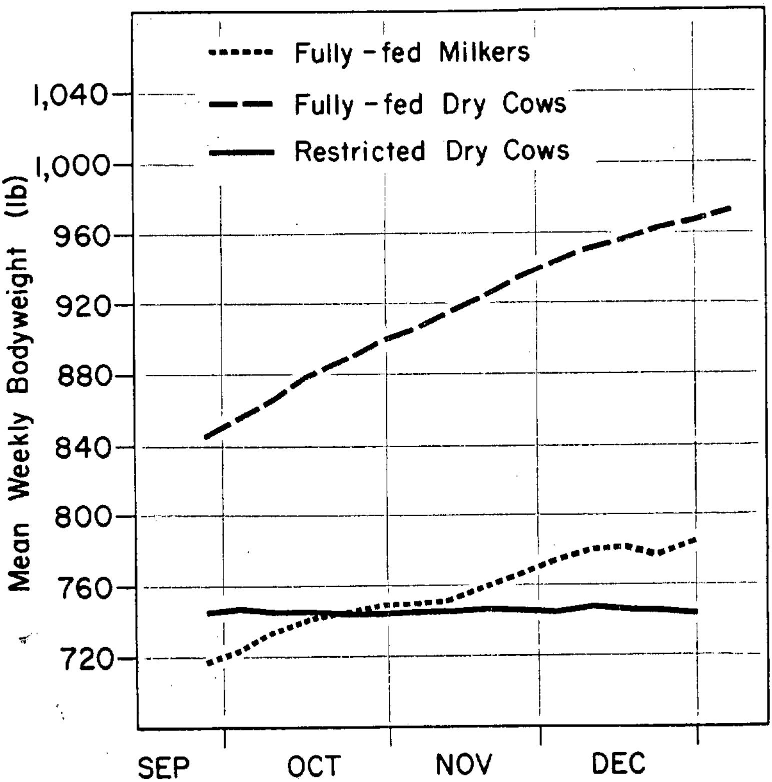

Fig. 3: Mean weekly body weights of dry and milking cows (lb). 1959-1962.

TRIAL 2

The results of Trial 2 can be seen by reference to the appropriate lines in Figures 1, 2 and 3. The mean dry matter intake of the fully-fed dry cattle is approximately 2.5 times higher than for the restricted cows. The mean herbage digestibilities are slightly but consistently higher for the former than for the lactating cows, and, whereas the weight of the restricted cows remained constant for 15 weeks, the fully-fed cattle increased in body weight at a mean rate of 1.3 lb per day. From Fig. 3 it is also apparent that the mean weight of the fully-fed dry cows was considerably higher in mid-September than that for the restricted animals. This was due to the different starting dates for each experiment, the delay in regard to the restricted group being necessitated by feed shortages. The comparison of fully-fed drys with their lactating twin mates commenced some 10 to 12 weeks earlier and, as reported previously, the mean weights of the latter two groups were at that stage 755 and 760 lb respectively.

The results contained in Fig. 4 show that, for the fully-fed dry cows, voluntary intake of D.O.M. remained consistently high during September to early December. This occurred despite the marked fall in digestibility during this period, and was due to a steady increase in dry matter intake (Fig. 1). Thus a maximum dry matter intake for these cattle of 21 lb/day was recorded in late November when the mean digestibility of the herbage organic matter had fallen from 81.5% to 76% and when the group mean body weight was 923 lb.

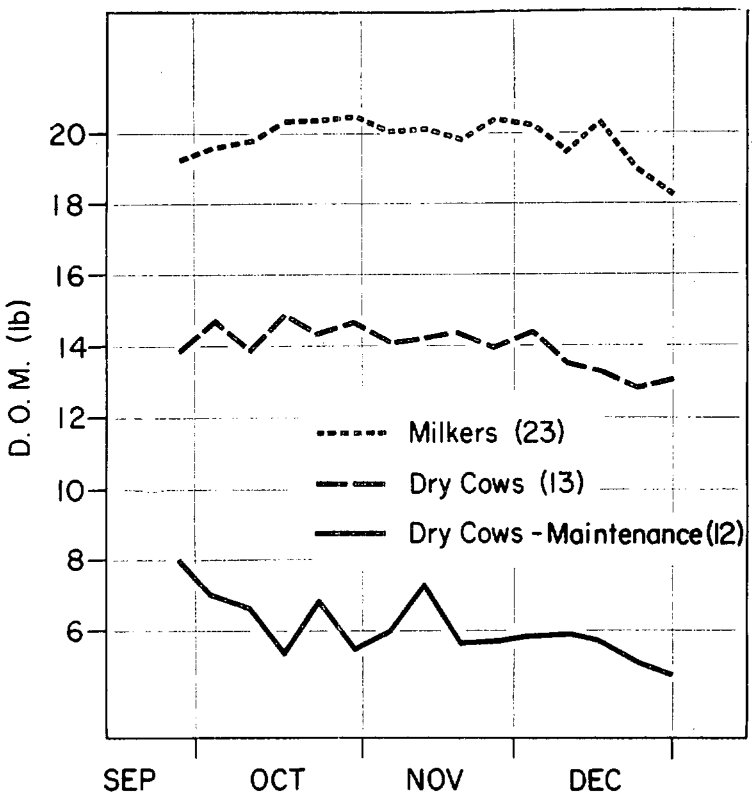

Fig. 4: Mean daily intake of digestible organic matter (lb), 1959-1962.

TABLE 1: COMPARISON OF ACTUAL AND ESTIMATED DAILY D.O.M. INTAKES (LB) OF FULL-FED STALLED DRY COWS (September-December, 1960-61, 1961-62)

Actual	*Estimated*	*Difference*
15.6	14.4	—1.2
15.1	14.3	—0.8
14.5	14.8	+0.3
14.5	13.7	—0.8
14.3	14.0	—0.3
14.3	13.9	—0.4
14.0	15.9	+1.9
14.0	13.4	—0.6
13.9	12.9	—1.0
13.4	14.7	+1.3
13.4	12.9	—0.5
13.2	13.6	+0.4
11.1	12.5	+1.4

D.O.M. (lb/cow/day) = 0.070 L.W.$^{0.73}$ + 2.92 L.W.G.

To try to measure the fractions of the feed ingested which were required for liveweight gain and for maintenance separately, the relationship of daily D.O.M. intake to L.W.$^{0.73}$ and daily liveweight change was determined by the method of least squares. Both the equation derived and a comparison of actual intakes with those obtained by using this equation are presented in Table 1. The two partial regression coefficients were highly significant, and when tested the equation was found to pass through the origin. As might have been anticipated in view of problems associated with the accurate meansurement of liveweight gain, the standard error of the coefficient derived for this term was quite high (0.80) but the coefficient of variation of prediction for the overall equation (7.5%) was reasonable. Conversion to S.E. of the value of 2.9 lb D.O.M. per 1 lb liveweight gain, derived from this equation, provides a value for fattening cattle of this size which, according to *Rations for Livestock* (1960), is very close to the theoretical requirement.

On the other hand, if it be accepted that, by adjusting body weight to its 0.73 power an expression is obtained of an animal's maintenance requirement, the coefficient associated with this term in the above equation will provide estimates considerably in excess of those contained in standard feeding tables. For example, application of this equation to a 1,000 lb cow yields a value of 9.7 lb D.O.M. for the maintenance requirement; this is approximately 30% higher than that obtained using the same pasture herbage but employing the traditionally accepted method of estimating an animal's maintenance requirement. The data contained in Table 1 show that there is no reason to doubt the validity of this equation as applied to the results from the current experiments, and the methods employed preclude any biases in the measurement of feed intake.

TRIAL 3

The pooling of data from 1959-60, 1960-61 and 1961-62 was found necessary because of the numbers of animals required for statistical analysis. Mean calving dates were almost identical in 1959-60 and 1960-61 but, because of breeding problems, in 1961-62 the average date was approximately one month later. This was reflected in a small production difference, but the trend in milk production was similar for each season. There was also a slightly higher mean body weight recorded in 1961-62 owing to the presence of a higher proportion of mature cows in this particular year.

Between-season similarities in the quality of the herbage eaten were reflected in the digestibility coefficients calculated for each year, and, by comparison with the overall changes in digestibility during the 15-week trial period, inter-season differences were small.

For these reasons, the bulking of data from separate seasons appeared reasonable, particularly in view of the precautions taken to ensure the accurate measurement of intake.

Figure 1 shows that the mean dry matter intake of the milking cows increased steadily from mid-September and continued its upward trend for three to four weeks longer than was noted for the dry cattle. The maximum mean daily intake of 29 lb of dry matter was recorded during the third week in December. At this stage the digestibility of the herbage organic matter had fallen below values recorded at the start of the trial by approximately 6.5 digestibility units.

At this stage, dry matter consumption of the lactating cattle was approximately 3.5 times that of the group being fed a maintenance ration and 2.5 times that measured for the fully-fed, non-lactating group.

In spite of such large intake differences, which also applied to D.O.M., the average rate of liveweight gain for the milking cows (0.70 lb/day) was considerably lower than for the dry cattle. In addition, the average yield of F.C.M. fell steadily throughout this period, from approximately 34 lb in September to 28 lb in late December - early January (Fig. 5).

Least squares analysis was again employed to partition the variance of D.O.M./cow/day, between the mean daily yield

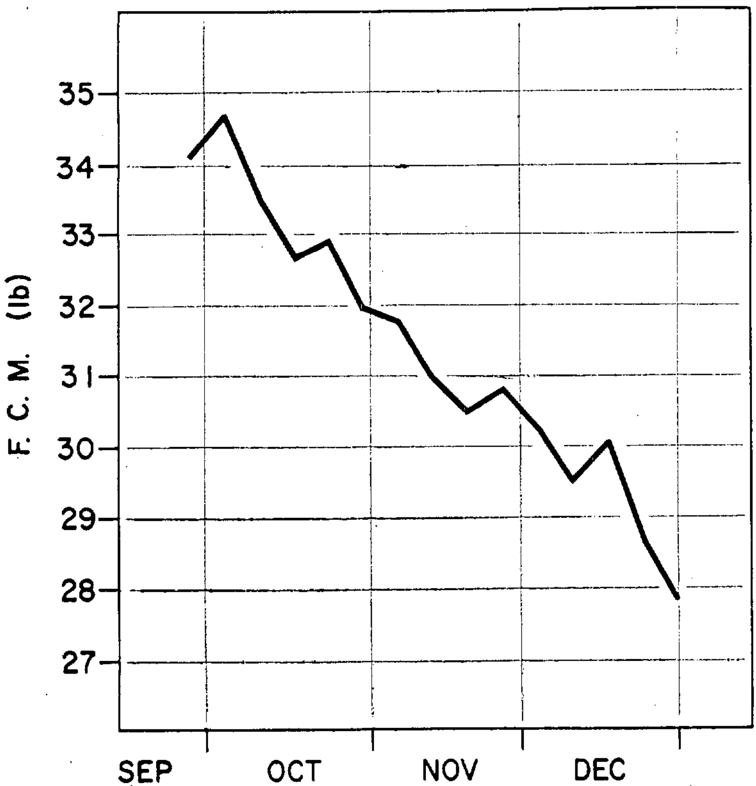

Fig. 5: Mean daily milk yield for 23 cows. 1959-1962.

of F.C.M., mean L.W.$^{0.73}$ and mean L.W.C. The multiple regression equation derived from the information for the 23 cows is presented in Table 2 together with a comparison of the D.O.M. intakes estimated from it and actual values for the individual cows. It will be noted that the deviations are all relatively small.

The regression equation was found to pass through the origin, both the coefficients for F.C.M. and L.W.$^{0.73}$ were shown to be very highly significant, and the coefficient for L.W.C. was significant at the 5% level.

Again the point of greatest interest is the size of these coefficients, and if it is accepted that the method used is a reasonable one for making assessments of animal requirements under conditions of full feeding, then the following points are of considerable importance:

TABLE 2: COMPARISON OF ACTUAL AND ESTIMATED DAILY D.O.M. INTAKES (LB) OF STALL-FED MILKING COWS

(September-December, 1959-60, 1960-61, 1961-62)

Actual	*Estimated*	*Difference*	*Actual*	*Estimated*	*Difference*
22.9	24.4	+1.5	19.7	19.2	—0.5
22.8	22.4	—0.4	19.6	20.1	+0.5
22.7	22.3	—0.4	18.8	20.1	+1.3
22.6	21.8	—0.8	18.6	18.2	—0.4
22.3	20.7	—1.6	18.2	18.5	+0.3
21.2	21.7	+0.5	17.8	18.4	+0.6
21.1	19.9	—1.2	17.6	17.9	+0.3
20.7	21.9	+1.2	17.2	16.8	—0.4
20.7	19.4	—1.3	17.1	17.2	+0.1
20.5	19.4	—1.1	16.5	16.2	—0.3
20.1	19.6	—0.5	15.8	16.6	+0.8
19.9	21.6	+1.7			

D.O.M. (lb/cow/day) = 0.21 F.C.M. + 0.095 L.W.$^{0.73}$ + 1.64 L.W.G.

(1) The feed requirement for fat corrected milk is considerably lower than that generally considered necessary for cows producing milk containing fat at the 4% level. It is also considerably lower than values previously reported by Wallace (1956) and (1961) using essentially the same technique as has been applied here. However, figures available in the literature mainly refer to complete or very large parts of lactations, and Wallace (1959) has presented some indirect evidence that the net efficiency of milk production declines as lactation advances.

The present experiment deals with a period of approximately four months when the cows are in very high production, with a process which, energetically, is highly efficient in the conversion of protein (Möllgaard, 1923) and with a process which, as has been shown by the work of Folley (1956), is dependent on the provision of acetic acid. Under these conditions the conversion of approximately 420 calories of digestible energy to 340 calories of net energy appears to be physiologically reasonable.

(2) The coefficient 0.095 associated with the term L.W.$^{0.73}$ is extremely high. If it be accepted that this is a true measure of the maintenance requirement of milking cows fed to appetite on pasture, then a 1,000 lb cow at this particular stage of her lactation and on feed of the type provided in this experiment will require 13.8 lb of D.O.M. for this purpose. This should be compared with the values of 9.7 and 7.4 lb

D.O.M. listed earlier in this paper as comparable requirements for fully-fed and restricted dry cattle, respectively.

The particularly high value for milking cows is roughly in agreement with that calculated by Wallace (1956) for cattle grazing outdoors, but the latter work was criticized because of a seasonal bias introduced when the general regression equation was applied to individual weeks.

Figure 6 demonstrates the result of applying a general regression equation derived from the present data to each of the 15 weeks, and, as was shown by Wallace (1961) with an example which was in many ways similar, there is a reasonable distribution of estimated values about the actual intake line. It will be noted that the equation used in Fig. 6 does not include

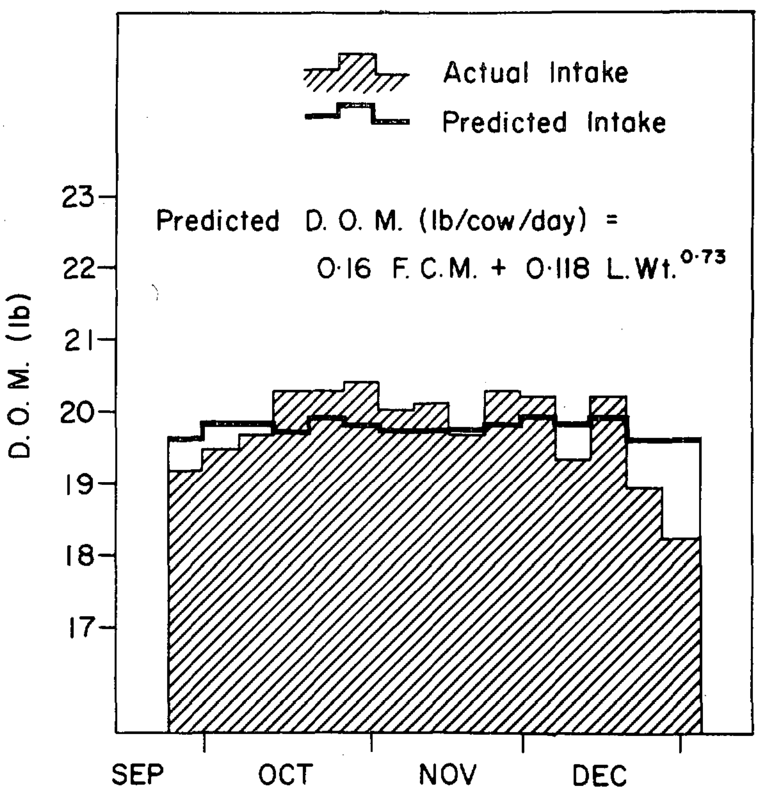

Fig. 6: Prediction of mean D.O.M. intake of 23 milking cows for individual weeks, 1959-1962.

the liveweight change term. The reason for deleting this is the same as was advanced by Wallace (1961), namely that much of the week-to-week variation in L.W.C. is due to fluctuations in gut fill. In estimating differences in intake for short periods, therefore, it is probably more accurate to neglect this term entirely.

At the 8th International Grassland Congress (1960) Corbett strongly criticized the maintenance requirement proposed by Wallace in 1956 for pasture-fed cattle. Subsequently, Wallace (1961) presented data which discounted certain of Corbett's objections. More recently, however, the latter as part of a paper read to the 8th International Congress on Animal Production at Hamburg has proposed an alternative equation, which he considers most satisfactorily describes the feed-intake-animal-output relationships applying to dairy cattle at pasture.

Apart from the rather vexed question of the manner in which this equation was derived, it may be considered reasonable to compare the estimates of D.O.M. intake derived by applying this relationship to the latest Ruakura data, with those obtained by using both Wallace's (1956) equation and the equation which applies specifically to the current results.

This comparison is summarized in Table 3 and it is quite clear that, by applying Corbett's relationship, a considerable underestimation of feed intake will be made. On the other hand, Wallace's equation overestimates intake, but this is almost solely due to a higher allowance for F.C.M. In this regard, it should be recalled that the latter equation is calculated from a series of virtually complete lactations. Both Corbett's data and those presented in this paper refer to imited periods totalling approximately four months.

TABLE 3: COMPARISON OF ACTUAL AND ESTIMATED GROUP MEAN DAILY D.O.M. INTAKES OF MILKING COWS (September-December, 1959-60, 1960-61, 1961-62)

	lb/D.O.M./Cow/Day					
Actual	*Estimated*			*Difference*		
	(1)	(2)	(3)	(1)—A	(2)—A	(3)—A
19.8	19.8	23.1	15.6	0.0	+3.3	—4.2

(1) D.O.M. = 0.21 F.C.M. + 0.095 $L.W.^{0.73}$ + 1.64 L.W.C. (Hutton, 1962).

(2) D.O.M. = 0.35 F.C.M. + 0.08 $L.W.^{0.73}$ + 3.0 L.W.C. (Wallace, 1956).

(3) D.O.M. = 0.30 F.C.M. + 0.046 $L.W.^{0.73}$ + 0.56 L.W.C. (Corbett, 1961).

The coefficient of variation of prediction (4.8%) which is applicable to the present equation shows that the coefficient 0.095 describes the relationship of D.O.M. intake to L.W.$^{0.73}$ for Ruakura cattle under the local conditions of pasture growth and feeding, with a high degree of accuracy.

Why, then, is there such a large discrepancy between the results reported from Ruakura and those reported overseas? It is probably largely due to intake differences. For example, Corbett (1961), while not providing specific information on actual intakes, suggests that the equation previously shown in Table 3 adequately fits his data. Using this, it may be calculated that a 1,000 lb cow producing three gallons of F.C.M. per day and increasing in liveweight at the rate of 0.5 lb/day will consume 16.4 lb of D.O.M., whereas New Zealand experience suggests that approximately 22 lb of D.O.M. will be required. Four possible explanations can be suggested for this discrepancy:

(1) The cows used by Corbett were more efficient converters of grass than were those used in the local trials.

(2) The herbage produced in the north-east of Scotland has a much higher nutritive value than that available at Ruakura.

(3) A severe restriction was being imposed upon the intake of Corbett's grazing cattle by the system of pasture management employed. In such circumstances the decline in F.C.M. production would have been much faster than occurred with the Ruakura cattle.

(4) There may have been certain errors inherent in the indirect method used by Corbett for estimating intake.

Since both (1) and (2) are rather unlikely, the discrepancy between the results obtained at the Rowett and Ruakura Research Stations is probably due to a combination of (3) and (4).

If, however, it is accepted that the large coefficients associated with L.W.$^{0.73}$ are appropriate to New Zealand feeding conditions and to this particular form of analysis, how can these large increases in what is termed the maintenance requirement be explained physiologically? It may perhaps be justifiably said that application of the method of least squares to these data is scarcely appropriate, since we are attempting to partition the variance of D.O.M. between two or three terms which are each functions of net energy. This may be perfectly true, but the size of the coefficients of variation of prediction previously presented for fully-fed dry and lactating cattle, shows that reasonably accurate estimates of intake can be made in this way.

The answer to this probably lies in differences between what in the past has been largely an empirical definition of maintenance, and what under conditions of full-feeding and lactation can legitimately be included in this term. The maintenance requirements listed in feeding tables have been derived largely from experiments with fasting animals and the maintenance values have subsequently been calculated as functions of basal metabolism. This provides the link with the term L.W.$^{0.73}$.

Considering the maintenance requirement of an individual as the sum of the basal metabolic rates of all the individual organs and parts, then it would seem logical that, as certain of the former increase in size with plane of nutrition and lactation, their increased energy costs should constitute a maintenance charge.

The experiments of Ritzman and Benedict (1938), Marston (1948) and Mitchell *et al.* (1941) have all shown that previous plane of nutrition will affect estimates of fasting heat production. Ritzman and Benedict (1938) have also described trials in which they found that the fasting heat production of cows which had temporarily ceased lactation was considerably higher than when the animals were dry.

The conditions of these experiments are scarcely comparable with those described here, but they point to probable errors in existing feeding standards when these are applied to animals both eating to appetite and lactating.

From theoretical considerations, one of the greatest disadvantages associated with the term L.W.$^{0.73}$ is that, through its relationship to body surface area, it not only provides a measure of basal metabolism, but it is also related to the heat disposing capacity of the animal at all feeding levels. It is quite probable, therefore, that where increased heat increments of feeding associated with high intake levels are obtained, these will be found included in the term L.W.$^{0.73}$ in equations of the type presented in this paper. This is likely to be particularly important where pasture herbage of low digestibility, yielding rumen breakdown products high in acetic acid is fed in large amounts to fattening and lactating stock. Such an additional heat increment would be indistinguishable from the legitimate energy costs of mainenance and could markedly increase the size of the coefficient associated with L.W.$^{0.73}$.

For this reason, and until this particular question has been resolved, it may prove wiser in future when partitioning D.O.M. in the way that has been done here, to refer to the fraction of the D.O.M. associated with L.W.$^{0.73}$ rather than to the D.O.M. required for maintenance.

It will be apparent from the results presented here that more possibilities have been raised by these experiments than problems fully answered. There is an obvious need for correlating the results of stall-feeding trials of this type with calorimetry studies conducted on the same animals and feeds. There is an obvious need to extend these trials to larger groups of animals and to wider ranges of feeding. Ultimately, the results must be translated into a form which can be used on the farm and, to this end, methods for measuring intake in the field must be improved.

This stepwise procedure appears to be a logical approach towards an understanding of the feed requirements of pasture-fed stock and the feeding value of pasture herbages.

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DISCUSSION

Q: *Does Dr Hutton believe that under the high ambient temperature conditions which at times apply in the Waikato, the ability of fully-fed animals to dissipate energy as heat will be markedly impaired?*

DR J. B. HUTTON: I do not know. If ambient temperatures exceed the critical values for dairy cattle, intakes generally fall. There is no evidence that intake fell under high temperature conditions in the present experiments.