THE VOLUNTARY INTAKE OF THE LACTATING DAIRY COW AND ITS RELATION TO DIGESTION

J. B. HUTTON, J. W. HUGHES, R. P. NEWTH and K. WATANABE*

Ruakura Agricultural Research Centre, Hamilton

SUMMARY

Differences in voluntary intake, milk production and in the apparent digestibility of energy consumed by fistulated and non-fistulated twin cattle were examined using cows fed exclusively on fresh pasture herbage over a full lactational period. Both intakes and productions of the fistulated cattle were consistently lower than those of their non-fistulated twins.

For the former, estimates were obtained of the quantities of ingesta present in the reticulo-rumen, and the rate of flow of fluid through the reticulo-omasal orifice was also determined. These were related to dry matter intake and to the apparent digestibility of the herbage energy consumed.

Highly significant regressions of D.M. intake on the amount of D.M. present in the reticulo-rumen and on total fill were obtained. Application of these relations to the prediction of gut fill in non-fistulated cattle is discussed.

The possibility that voluntary intake in the lactating grazing cow might be limited by the physical capacity of the reticulo-rumen was also examined, but no evidence to support this was obtained.

AT THE CONCLUSION of a recent review article on regulation of voluntary food intake in ruminants, Balch and Campling (1962) made the following comments: "There is need for much work on the regulation of food intake in ruminants during growth, fattening, pregnancy, lactation and the dry period. The interpretation of much previous work has been hampered by lack of supporting information. Observations on the amount of the gut contents, digestibility of the food, rate of passage, type of rumen fermentation, concentration of blood constituents, energy balance and body composition are all required."

Absence of information of this type applies particularly to pastoral feeding conditions, where level of voluntary intake has a special significance in relation to productive performance. With the object of trying to remedy certain of these deficiencies, and to obtain information which more specifically might assist in explaining patterns of voluntary intake in the lactating dairy cow, a series of detailed feeding

* On leave from the National Institute of Animal Industry, Japan.

trials were initiated at Ruakura Agricultural Research Centre in the 1962–63 dairying season.

It is proposed in this paper to consider only those aspects of the experiments relating to the measurement of rumen fill, rate of passage of digesta, herbage digestibility and intake, and to examine the relations between these.

For most aspects of this work, it was necessary to use rumen fistulated cattle. The procedure adopted was to fistulate one member of a pair of identical twins and to use the second member as a control. Both cows were then subjected to the same feeding and management conditions. The use of control animals was considered desirable for determining whether quantitative changes obtained with normal lactating cows could reasonably be interpreted from results with fistulated stock. In presenting the results, therefore, intake, production and digestibility data have been included for both twin members.

EXPERIMENTAL

ANIMALS

Two sets of identical twin Jersey crossbred cattle were used. Both were 4 years old and had completed two lactations. Mean liveweights for the complete experimental period were for the pair 071 and 072, 809 lb and 868 lb, and for the second pair 079 and 080, 653 lb and 683 lb, respectively. In each case the fistulated animal was the lighter. Cows were fistulated in late pregnancy, the cannula and bung used being an adaptation of that described by Balch and Johnson (1948).

All cows calved within 7 days of one another in late July, 1962, and they remained in milk for 46 weeks.

FEEDING AND MANAGEMENT

From approximately two weeks before calving, and continuously thereafter, the cows were stall fed and, with the exception of a period of two weeks in late summer, they received fresh pasture herbage to appetite each day. Between August and December this was dominantly perennial ryegrass, white clover and *Poa trivialis;* from December to April it was paspalum dominant, and between April and June returned to a mixture of ryegrass and white clover.

The system of feeding and management of the stalled cattle was as described in detail previously (Hutton, 1962).

Between March 27, 1963, and April 10, 1963, a shortage of fresh pasture herbage necessitated the feeding of a hay and concentrate mixture. Results obtained during this period will not be presented.

Feed intakes were measured each day and are presented as means (lb/cow/day) for successive weekly periods. They are also calculated as 10-day means during digestibility trials, and as 6-day means for comparison with measurements of rumen fill.

Estimation of the Apparent Digestibility of the Herbage Energy Consumed

Within three weeks of calving, and at monthly intervals thereafter, estimates were obtained of the apparent digestibility of the herbage energy consumed. Ten trials were undertaken on pasture herbage during the 46-week experimental period, which extended from the last week in July, 1962, until the end of the first week in June, 1963.

Apparent digestibilities were calculated from the mean quantities of feed consumed and faeces voided in each 10-day period.

Estimation of Total Fill in the Reticulo-rumen and Rate of Fluid Outflow

Fluid Volume and Flow Rate

These were estimated by using polyethylene glycol (M.W. 4000) (PEG) as an indigestible marker, after the manner described by Hydén (1961). This involves introducing a known quantity of marker dissolved in water into the reticulo-rumen and measuring its rate of disappearance. Rate of flow is determined from the slope of the line relating marker concentration to time. On an arithmetical scale this is curvilinear, but is converted to a linear form by expressing marker concentration as its natural logarithm. By extrapolating back along this line to the time at which the marker was administered, an estimate is obtained of what the concentration would have been if complete dispersion had occurred at the time of administration.

Volume is then calculated from the estimate of marker concentration at zero time and the total quantity of PEG used. The basic assumption made when calculating volume and flow rate by this method is that, under conditions in which the animals have continuous access to feed and

water, both of the former remain relatively constant over the experimental period.

In the present experiment, two preliminary trials, each lasting three days, were undertaken with both fistulated cows, one in the second week before calving, the other in the first week after calving. No information on herbage digestibilities is available for either period. Thereafter fluid volumes and flow rates were measured over five successive days in each 10-day digestibility trial period.

Each day at 8.30 a.m. approximately 250 grams of PEG dissolved in 2 litres of water were introduced into the reticulo-rumen through the fistula by means of a drenching gun. A length of rubber tubing attached to the delivery end of this was used to speed marker distribution, being directed by arm to various depths and positions in the rumen. Samples of rumen liquor were withdrawn at the following times after dosing: 1½, 3, 6, 9, 12 and 24 hours. Marker concentrations were determined by the method of Hydén (1955). Similar analyses were carried out on representative samples of faeces for measuring the percentage recovery, and on samples of the solutions infused, to provide an accurate measure of the quantities of PEG used.

In calculating fluid volumes and flow rates, analyses were restricted to the first 12 hours of the marker disappearance curves. This was necessitated by the system of feeding which it was practicable to employ and by the quantities of PEG required.

Amount of Dry Matter in the Reticulo-rumen

This was calculated from the estimated average fluid volume for each period, and from estimates of the average percentage dry matter of the digesta. The latter were obtained from samples taken at the times indicated previously, and dried in a Unitherm oven at 70°C.

Milk Production

This was measured in lb butterfat for the full lactation period.

RESULTS

Feed Intake and Production

The mean daily dry matter intakes of all cows are shown in Fig. 1. Both within and between twin sets, the trends in voluntary intake from calving are similar to those discussed previously by Hutton (1963), low levels of feed

consumption being recorded in the period of peak production, and highest levels being achieved some 3 to 4 months later. In each case, the feed intake of the fistulated cow was markedly lower than that of its co-twin, mean values for cows 071 and 072 being 24.9 and 28.2 lb D.M./day, and for cows 079 and 080, 22.4 and 23.8 lb/day,

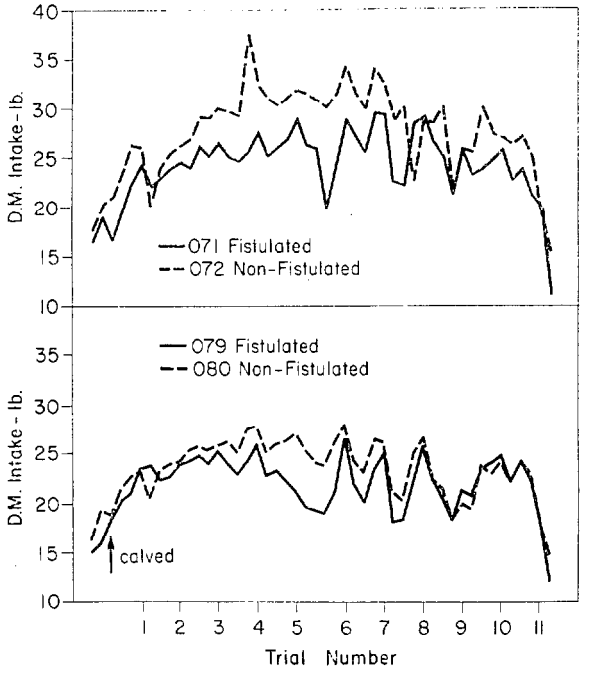

Fig. 1: Seasonal changes in voluntary D.M. intake.

respectively. These differences are reflected in the production records, the respective total butterfat productions of the first-mentioned pair being 316 and 429 lb, and of the second pair, 320 and 373 lb. By comparison with these differences, in each case favouring the normal animal by approximately 100 lb and 50 lb of butterfat, the means of the previous two seasons' productions differed by only 18 lb and 5 lb.

Herbage Digestibility

Changes in the apparent digestibility of the energy in the herbage consumed are shown for both sets of cows in Fig. 2. Within and between set differences are small, but between trials, the herbage digestibility varied from 77%

in late winter-early spring, to 65% in late summer. There was no significant relation between D.M. intake and percentage digestibility for any of the cows.

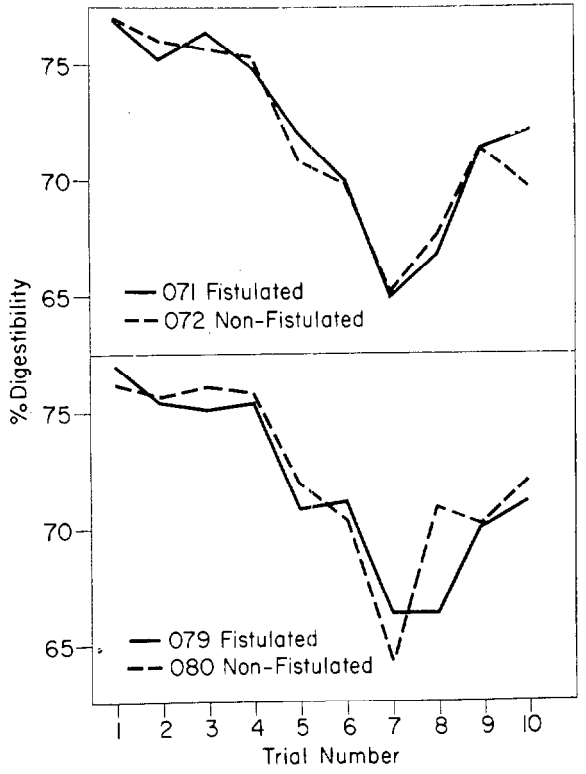

Fig. 2: Seasonal changes in the apparent digestibility of the energy consumed.

Contents of the Reticulo-rumen

During the full experimental period and while the cows were being fed solely on pasture herbage, 112 infusions of PEG were made. Of these, 90% resulted in marker disappearance curves providing a very good relation between the log. of the marker concentration and time. As the remainder were distributed through a number of trials and were not restricted to one particular period, all data were analysed using the form of the exponential equation proposed by Hydén (1961).

Volume of Fluid in the Reticulo-rumen

The mean estimates of fluid volume and the within trial range in these is shown in Fig. 3. There is evidence from both cows that a rapid increase occurs in the amount of fluid in the reticulo-rumen during the first month post-calving. Thereafter there is considerable variation between trials, average estimates derived from the ten 10-day trials being 10.4 ± 0.6 gallons for cow 071, and 8.2 ± 0.7 gallons for cow 079. These were equivalent on a weight basis to 12.9% and 12.6% of the respective live-weights of each cow.

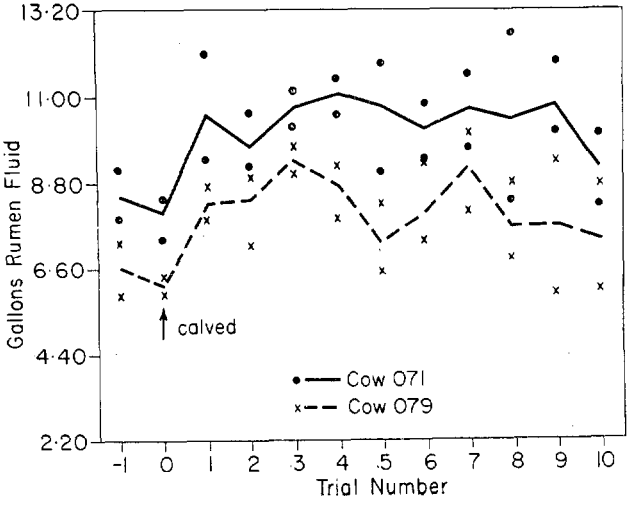

Fig. 3: Changes in the amount of fluid present in the reticulo-rumen.

Analysis of data on the percentage recovery of PEG from samples representative of faeces voided during these trials gave mean values of 93 ± 5% for cow 071 and 95 ± 8% for cow 079.

Relation between Volume of Fluid in the Reticulo-rumen and Dry Matter Intake

Mean values from all trials have been used in calculating this relation, which is shown for each cow in Fig. 4.

Separate relations both showing a positive correlation between these variables are obviously appropriate. On the one hand, for the larger animal with the wider intake range, the regression of fluid volume on intake was curvilinear, increasing feed consumption above about 26 lb/day having little effect on the amount of fluid present in

the rumen. This relation was described by the following quadratic equation:
90% of the variation in V was associated with this regression relation. On the other hand, the regression calculated for the smaller cow was linear, volume being found directly proportional to intake, as shown in the equation.

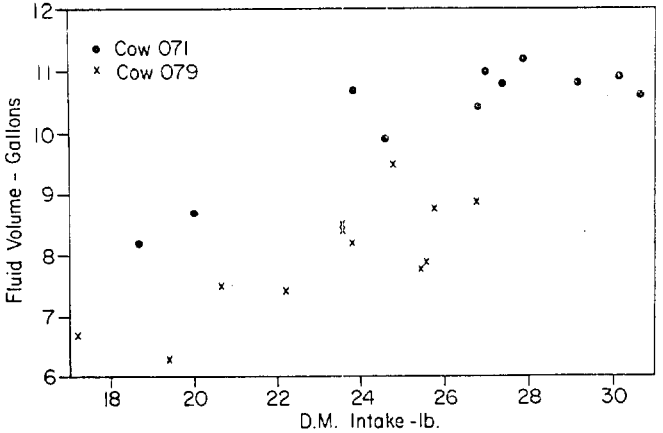

Fig. 4: Relation between the volume of fluid in the reticulo-rumen and D.M. intake.

$$V = 1.486 \pm_{0.376} x_1 - 0.026 \pm_{0.007} x_2 - 10.944 \pm 0.339 (3.4\%)$$

where V = fluid volume in gallons,
x_1 = D.M. intake (lb)
$x_2 = x_1^2$

$$V = 0.337 \pm_{0.062} x \pm 0.596 (7.6\%)$$

V and x refer to the same terms as in the previous equation. 65% of the variation in V was accounted for by this relation.

Thus, with each 1 lb change in the D.M. consumption of this cow, fluid volume increased by approximately one-third gallon.

Weight of Dry Matter in the Reticulo-rumen

As calculated from the ten trial means, the average quantities present over the full lactation period were 16.5 ± 2.3 lb for cow 071 and 13.3 ± 1.3 lb for cow 079, representing 61% and 55% of the respective daily D.M. intakes recorded over the same period.

Change in the percentage dry matter of rumen digesta was closely associated both with changes in the apparent digestibility of the herbage energy and with D.M. intake,

86% of the variation in rumen D.M. percentage being accounted for by these two variables.

Relation between the Amounts of D.M. Consumed and Present in the Reticulo-rumen

No significant difference was found between the slopes of the individual cow regressions of rumen D.M. on D.M. intake. Differences between the intercepts calculated for these separate equations were highly significant, however. The lines and equations shown in Fig. 5 were therefore calculated from the "within-cow" component of this regression analysis.

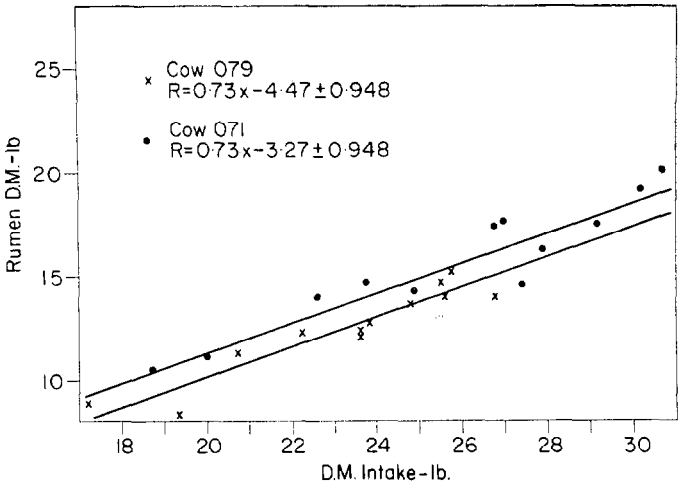

Fig. 5: Relation between the weight of D.M. in the reticulo-rumen and D.M. intake.

The effect of the percentage digestibility of the herbage consumed on the amount of D.M. present in the rumen was also examined in these analyses. When related to rumen D.M. either alone or in combination with D.M. intake, percentage digestibility accounted for a highly significant fraction of the variance for each cow. For reasons similar to those previously outlined in calculating the multiple regression of rumen D.M. (R) on D.M. intake and percentage digestibility, the analysis was based on "within-cow" variation. 90% of the variation in R was accounted for in the case of each animal by the relations calculated in this way.

The equations derived are as follows:

$$R_{071} = 14.17 + 0.58_{\pm 0.07}\, x_1 - 0.19_{\pm 0.04}\, x_2 \pm 0.586(3.5\%)$$

and $$R_{079} = 12.51 + 0.58_{\pm 0.07}\, x_1 - 0.19_{\pm 0.04}\, x_2 \pm 0.586(4.4\%)$$

where R = Rumen D.M. (lb)
x_1 = D.M. intake (lb/cow/day)
x_2 = % apparent digestibility

From this it can be deduced, for both cows, that on herbage of constant digestibility a change of 1 lb dry matter intake will result in a like change of approximately 0.6 lb in the amount of D.M. present in the rumen, and that at constant intake a fall of one digestibility unit will result in an increase of approximately 0.2 lb in rumen D.M. In this interpretation no reference has been made to the possible influence of changing flow rate on these relations. Although most of the between-cow differences were accounted for by differing relative flow rates, the contribution of the latter to a reduction of within-cow variation was not significant.

Rate of Fluid Flow

Mean relative flow rates of fluid from the reticulo-rumen through the reticulo-omasal orifice are shown for successive trials in Fig. 6. Relative flow rate is expressed as a percentage of volume per hour. The overall mean for the ten 10-day trial periods was 21.6 ± 1.7% for cow 071, and

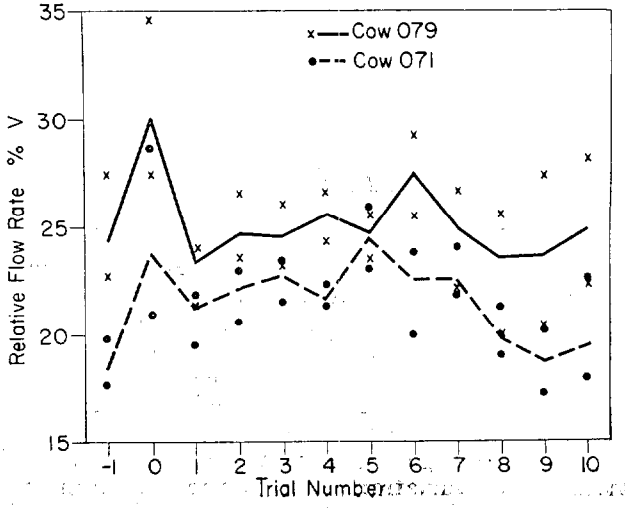

Fig. 6: Changes in the rate of flow of fluid through the reticulo-omasal orifice.

24.7 ± 1.2% for cow 079. These are equivalent to a flow rate of approximately 2 gal/hr. Particularly in the case of the larger animal, the relative flow rate appears to decline fairly steadily in late lactation.

In his trials with non-pregnant sheep of the Swedish native breed, Hydén (1961) obtained flow rates equivalent to 6.4% of the fluid volume per hour. These animals were fed about the maintenance level, and Hydén (*loc. cit.*) commented that, although available data gave no clear indication of a relation between dry matter intake and rate of flow, it seemed probable that increased food consumption and metabolism in productive animals should influence this. Present data confirm the accuracy of this assumption.

Between fasting and a maintenance feeding level, Hydén (*loc. cit.*) also found that little change occurred in the volume of fluid present in the reticulo-rumen. At relatively much higher intake levels, however, it has been found in the present trials that quite marked changes occur in volume and flow rate with a change in the level of feed consumption.

Relation of Flow Rate to Fluid Volume

This is shown in Fig. 7. The individual regression lines were again calculated from an analysis of "within-cow" variation. The slope of these indicates the nature and extent of the average change in flow rate with changing rumen volume over practically a complete 12-month period. Note that a similar relation applies to each cow. As shown

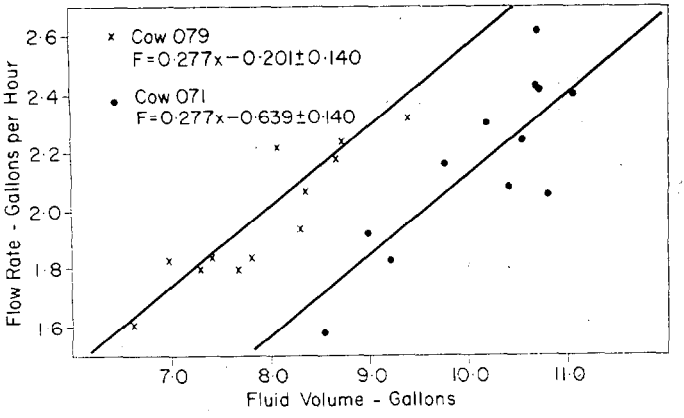

Fig. 7: Relation between the rate of fluid flow through the reticulo-omasal orifice and fluid volume.

by the following equations, in which F=flow rate (gal./hr) and x=volume (gal),

$$F_{0\cdot71} = 0.277 \pm 0.037\ x - 0.639 \pm 0.140$$

and $$F_{0\cdot79} = 0.277 \pm 0.037\ x - 0.201 \pm 0.140$$

this amounts to approximately 0.3 gal/hr for each 1 gal increase in fluid volume. 73% of the variation in F was associated with this regression relation.

The effect of total water intake on flow rate was also examined in this way, but was found non-significant.

DISCUSSION

While regression relations such as have been considered are extremely useful for quantifying known relations and examining others which one considers might exist, they may be of very limited assistance if one is interested primarily in separating cause from effect. Hence, without adequate information on the mechanism inducing and maintaining the appetite stimulus which occurs after calving, the relations between intake, fluid flow and volume cannot be satisfactorily interpreted in these terms.

In some circumstances, however, the actual form of a relation may prove of assistance. It will be recalled in the present experiment that there was a high positive correlation between rumen D.M. and D.M. intake. Regressions calculated for each cow were linear over the full range of intakes. Considerable evidence has been accumulated from overseas studies, however (Balch and Campling, 1962) that with bulky feeds (of which pasture is one) voluntary intake can be limited by the amount of digesta which the rumen accommodates. Had this been a significant factor in the present trials, one might have expected a curvilinear rather than a linear relation between rumen contents and dry matter intakes. An increase in relative flow rate with a rise in intake would also have been consistent with this possibility. Relative flow rates remained virtually unchanged at all intake levels, however. In a further analysis based on within-trial differences, the effect of daily changes in rumen fill on the following day's intake was measured. These results also supported the conclusion that, at the levels and with the foodstuffs consumed in the current trials, it is unlikely that actual physical bulk of material present in the reticulo-rumen has been an important factor restricting voluntary intake. This conclusion

could require qualification if continuous changes in actual rumen size occurred in association with change in fill.

Although no attempt was made to distinguish between rumen fill and size in these trials, it is hoped that work at present being undertaken by Dr N. M. Tulloh and J. W. Hughes will indicate the nature and extent of changes in rumen size during lactation.

Possible applications of a useful general relation between the total quantity of digesta in the reticulo-rumen and dry matter intake appear to justify an extension of this work. The limitations that variations in gut fill impose on live-weights as accurate measures of animal performance is well known. Since for cattle on all roughage diets, the digesta present in the reticulo-rumen accounts for at least 70% of total gut fill, its accurate prediction could be most useful in trials involving non-fistulated animals.

Which method is likely to prove best for such an investigation is not immediately apparent. No comparative data appear to be available on estimates of rumen fill obtained by the alternative procedures of marker dilution and manually emptying the rumen. For each method, information is required on ease of application, relative accuracy, and on the possible inducement of undesirable side effects on experimental animals.

These are some of the problems about which we are at present seeking information.

ACKNOWLEDGEMENTS

The contributions of the staff of the Nutrition section, particularly those of T. C. Jeffries and J. Parker, are greatly appreciated. Thanks are also due to K. E. Jury of the Biometrics section for helpful discussions, and for undertaking some of the analyses. The graphs are the work of the R.A.R.C. Art section.

REFERENCES

Balch, C. C., Campling, R. C., 1962: *Nutr. Abstr. Rev., 32*: 669.

Balch, C. C., Johnson, V. W., 1948: *Vet. Rec., 60*: 447.

Hutton, J. B., 1962: *Proc. N.Z. Soc. Anim. Prod., 22*: 12.
——— 1963: *Proc. N.Z. Soc. Anim. Prod., 23*: 39.

Hydén, S., 1955: *Ann. Roy. Agr. Coll., Sweden, 22*: 139.
——— 1961: *Kungl. Lantbrukshögskolars Annaler, 27*: 51.

DISCUSSION

PROFESSOR I. L. CAMPBELL: *With reference to the lack of relationship between intake and digestibility found in these data from lactating animals fed pasture, in contrast to some overseas results from dry sheep and cattle fed hay and dried grass, is it likely that the influence of stage of lactation on intake is masking a relationship, or rather that the nature of pasture as a foodstuff accounts for the difference in results?*

DR J. B. HUTTON: The relation was calculated making no adjustment, for stage of lactation. The important feature is that, in practice, under seasonal grazing conditions, percentage digestibility is not related to level of voluntary intake, and therefore is of little value as a predictor of the latter. This is of particular interest, since percentage digestibility is included for this purpose in Professor Crampton's Nutritive Value Index.

DR A. H. CARTER: *In view of the likely importance of rate of passage on the characters being studied, was information obtained on this factor* — e.g., *by sequential faecal sampling for PEG concentration? If so, was this estimated rate of passage related to reticulorumen flow rates?*

DR HUTTON: Because of the amount of additional work involved, in only one trial were sequential faecal analyses undertaken for PEG. Hence the relation suggested could not be examined. We attempted, however, to measure the rate of passage of feed residues by the alternative stained particle technique used by Balch and co-workers at the N.I.R.D., Reading. This method was not found sufficiently sensitive for the measurements we were trying to make.