
THE PROCEEDINGS OF THE
NEW ZEALAND SOCIETY
OF
ANIMAL PRODUCTION
VOLUME 62 2002

THE EFFECT OF STOCKING RATE AND CONCENTRATE FEEDING ON THE CONVERSION OF PASTURE TO MILK

C. P. McMeekan*

The main function of this paper is to summarize the nutritional aspects of Hancock's well known A-B-C experiment. This was primarily a genetic project, but since, in its design, three levels of feeding were involved and since the nutritional systems used bear a direct relation to alternative systems of feeding available to the New Zealand dairyman, examination of the production and nutritional data obtained is not without both theoretical and applied interest. Genetic aspects have been reported by Hancock (1954) and a full account of the nutritional side will shortly appear. A short summary only can be given here.

The basic design of Hancock's experiment was that monozygotic twins were split three ways into treatments 'A', 'B' and 'C'. The work extended over three years and a total of 90 lactations. In treatment 'A' the cows had free access to ample grass and in addition were offered 1 lb of a meal mixture for each 5 lb of milk produced. In treatment 'B' the cattle were full fed on grass alone and in treatment 'C' a restricted amount of grass only was available. The necessary differences in grass availability were obtained by varying the stocking rates. Thus the 'A' and 'B' cattle were run at the rate of one cow per acre and the 'C' cattle at the rate of one cow per 0.6 acre. All groups were rotationally grazed over 14 paddocks on a daily shift system.

Note that these treatments approximated three widely different levels of feed intake and that they covered the range of nutritional standards found on the New Zealand dairy farm. The 'A' treatment represents the conditions on many stud cattle farms where the main source of income is from the sale of breeding stock and where the objective of a high per cow yield as a basis of selection and sale is sought through the aid of supplementary concentrate feeding. The target is a production level approaching the ceiling of the inherent capacity of the stock. The 'B' treatment is typical of that class of grassland farm where cattle are maintained on a high even level of

**Superintendent, Ruakura Animal Research Station, Dept. of Agriculture, Private Bag, Hamilton.*

nutrition on grass supplemented when necessary with silage and hay. High, economic, per cow production is the target. The 'C' treatment is representative of a large number of farms where a heavy stocking rate results in underfeeding during periods of slow pasture growth. While believed to lead to low per cow production, it is argued that, because of the greater number of animals carried, per acre returns are higher than with cows fully fed on grass.

In Hancock's study the usual production data on growth, milk yield and milk composition were supplemented by periodic information on grazing behaviour. In addition, an attempt was made to measure the intake of the animals concerned. In this summary, production results are expressed in terms of 4% F.C.M. (fat corrected milk).

Effects on Milk Production

The three levels of nutrition induced wide differences in F.C.M. production. The maximum likelihood or least squares estimates of the treatment effects are shown in Table 1. On a per cow basis the cows of treatment 'A' out-produced those of treatment 'C' by 45% and those of treatment 'B' by 24%. Treatment 'B' cows out-produced those of treatment 'C' by 16%. It is clear that the enlargement of the grazing area from a level of severe restriction to ample pasture had a smaller effect on total milk production than had the addition of concentrates to a full grass diet.

TABLE 1: F.C.M. YIELD (GAL)

	A	*B*	*C*
Per cow	891	716	616
Ratio	145	116	100

While per cow yields increased with the level of feeding, per acre productions showed important differences. These are summarized in Table 2 from which it will be noted that per unit area the 'C' treatment produced the most milk and treatment 'B' the least. Rating 'C' again at 100, 'B' treatment, though 16% better on a per cow basis, yielded 30% less per acre. Since stocking rate was the same on 'A' and 'B' treatments, the higher per cow yield due to concentrates placed the 'A' area ahead of 'B' on a per acre basis. It is important to stress that, despite an additional 275 gal per cow in the 'A' treatment, the 'C' cows outyielded the 'A' cows by 135 gal per acre.

The comparative fat figures per acre are also shown. The level of 410 lb is of interest as a measure of the output per acre possible when cows only are run and stocking rate is at a very

TABLE 2: YIELD PER ACRE

	A	*B*	*C*
F.C.M. (gal)	891	716	1,026
Ratio	87	70	100
Fat(lb)	356	286	410

high level. Actual output per acre for this system was 453 lb. These figures might be compared with Wallace's (1957) estimates of potential output from grassland.

It must be mentioned that, while the relative differences shown are a fair summary of the situation, the absolute values per acre are subject to the weakness that all the hay and silage needed by the 'C' cows did not come off the area. In the three years, 35%, 27% and 32% of all areas were cut for silage and hay. These quantities, while more than adequate for treatments 'A' and 'B', were not sufficient for treatment 'C' where an amount of supplementary fodder equivalent to 3½% of total intake was brought on to the area. However, this small proportion is unlikely to materially affect the absolute values.

TABLE 3: FAT TEST

	A	*B*	*C*
Per cent.	5.07	4.96	4.84
Ratio	105	102	100

The influence of the treatments on butterfat percentage was much less marked (Table 3). The difference in fat content of the milk between the two pasture groups was approximately equal to the difference between groups 'A' and 'B', suggesting that concentrate feeding had approximately the same effect as the reduction of the grazing area. Summarizing the situation, it may be said that, while the 'A' and 'B' treatments increased the milk yield by 45% and 16% respectively, butterfat percentage increased by only 5 and 2%.

Feed Consumption and Efficiency of Utilization

Most of the data on pasture consumption have been derived from Wallace's formula (1956) based on milk yield, liveweight and liveweight gains. Amounts of meal, hay and silage fed were measured accurately. An elaborate cage-sampling and plucking technique aimed at a more objective assessment of grass intake failed to yield reliable results. The treatment thus has had to be somewhat hypothetical, though considerably less so than that commonly used by overseas workers attempting similar investigations.

TABLE 4: ANNUAL FEED INTAKE PER COW

	A	*B*	*C*
Total D.O.M.	7,548	6,386	6,121
Ratio	123	112	100
Pasture D.O.M.	5,939	6,084	5,513
Ratio	108	110	100

Estimates of intake of D.O.M. are summarized in Table 4. Pasture intake was calculated by deducting the D.O.M. values of the concentrates, hay and silage fed, digestibilities of which were independently determined.

The concentrate fed cows 'A' had an estimated intake of approximately 7,500 lb D.O.M. per cow per year, the full fed grass cows 'B' 6,800 lb and the restricted grass group 'C' 6,100 lb, relative ratios being 123, 112 and 100. Grass intakes of the 'A' and 'B' cows were similar at approximately 6,000 lb, while the full fed 'B' cows with 66% greater area available consumed only 10% more than the restricted group 'C' at 5,500 lb.

TABLE 5: PARTITION OF INTAKE (PER CENT.)

	A	*B*	*C*
Milk	35.4	31.4	30.2
Maintenance	59.2	63.2	66.3
Liveweight gain/loss	5.4	5.4	3.5

In Table 5 these total intake figures have been partitioned according to their use for milk, maintenance and liveweight gain. Efficiency in use of food for milk was apparently highest for the 'A' cows and lowest for the 'C' cows. When computed on this basis, the 'C' cows used the highest proportion for maintenance and the 'A' cows the least. Both 'A' and 'B' cows expended more food in liveweight gains. The increased milk yield of the better fed animals apparently more than compensated for their higher body weights. It is important to note that part of the greater intake of both full fed groups was used in the production of increased liveweight as well as more milk. Mean liveweights of all cattle at the commencement of the experiment were the same. At the end, the 'A' cows averaged 984 lb, 'B' 930 lb, and 'C' 806 lb.

Some evidence that the estimates presented are reasonably accurate was gained from a comparison of intakes measured by the Ruakura chromium/nitrogen method and those derived from the formula for the same periods. By the third year of the experiment, the Ruakura intake technique had been developed. This was used over three separate fortnightly periods during the last lactation. Agreement was reasonably good, though the estimates were slightly greater when measured as compared with the calculated figures.

It is of interest that, on the basis used, the consumption of considerable quantities of concentrates did not depress appreciably the consumption of grass by the cows concerned. The 'A' cows consumed only 145 lb D.O.M. of herbage and 62 lb of hay and silage less than the 'B' cows. It would appear, therefore, that the 850 lb D.O.M. derived from concentrates replaced only 200 lb of pasture. In later work, Wallace (1957) similarly reports the feeding of concentrates to have only a small effect on reducing grass intake.

Assuming that the theoretical D.O.M. requirements of the three groups are true reflections of their consumption of pasture, it is possible to compute the relative extent to which the cows harvested the pasture grown under the three systems. This has been done in Table 6.

TABLE 6: RELATIVE EFFICIENCY OF GRASS UTILIZATION

	A	*B*	*C*
Per cent.	64.6	66.2	100

Taking the utilization of the 'C' group as 100% the data show that the cows of the two other groups pasturing on a 66% larger area could not have consumed more than approximately two thirds of the grass actually grown. Even this may be an over-estimate, if it is assumed—as indeed is likely—that more grass grew per unit area on the 'A' and 'B' sections. In this connection it might be noted that the stocking rate even of the 'B' group area was high in relation to that commonly found in New Zealand where the level of one milking cow per acre is rarely approached.

Grazing Behaviour

Grazing behaviour on a 24-hour, 5-minute basis was observed at frequent stages throughout lactation in the first and last seasons.

Both grazing and ruminating activities were strongly influenced by treatment. The type of data arising are summarized in Table 7. The 'B' and specially the 'C' cows grazed a much longer time than did the 'A'. The short length and short supply of grass on the 'C' area induced the animals to spend an average of over two hours more per day in grazing than did their concentrate supplemented and full grass fed mates on the 'A' treatment. They grazed 1½ hours longer than the 'B' cows on the lower stocked area.

TABLE 7: GRAZING AND RUMINATING (MIN)

	A	B	C
Grazing	409	464	549
Ratio	75	85	100
Rumination	500	495	440
Ratio	114	113	100

On the other hand, the ruminating time of the 'C' cows was a full hour shorter than both the 'A' and 'B' animals. Thus, from relative rumination times alone it can be argued that, despite a much greater effort expended in ingesting pasture, the 'C' cows obtained markedly less feed than the animals of the other groups—since rumination time is closely related to feed intake. On the same argument, the similar ruminating times of the 'A' and 'B' cows suggest a comparable pasture intake, as indeed appeared to be the case from the estimates previously presented. The longer grazing time of the 'B' cows as compared with their 'A' mates is not explainable in terms of herbage availability. Ample grass was available on both treatments. Since intake and rumination times are both very similar, it is suggested that a possible explanation is that the 'A' cows, as a result of their readily available supply of concentrates, were less selective in their grazing and spent less time in the process than did their more selective and unsupplemented mates. Field observations support this hypothesis.

The close correlation between the intake and rumination time on similar feed has been demonstrated previously by Hancock (1952). During the last year of the present experiment, intake was measured by the Ruakura technique of chromium/nitrogen over three fortnightly periods during which time grazing observations were also made. Relative intakes and rumination times under the three treatments are summarized in Table 8 where it will be observed that the agreement was exceedingly close.

TABLE 8: INTAKE AND RUMINATION

	A	B	C
Intake	113	114	100
Rumination	113	115	100

Discussion

The results of this experiment indicate clearly that pasture herbage is not a perfect diet for dairy cattle, since concentrates are capable of giving a substantial lift in milk yield when added to an *ad lib.* diet of high quality pasture. It seems likely that this effect is due to dairy cows being capable of consuming some concentrates even when they have satisfied their appetite for pasture and not to specific constituents or associated effects of the concentrates. Wallace (1957) has previously suggested this based on subsequent work. If this viewpoint be true, it is obvious that one of the factors limiting maximum milk yield from grassland is the volume of grass which cows can consume even of good quality material. It is suggested that this apparent limitation should not be accepted as inevitable. Students of the New Zealand cow should interest themselves in the reasons and possible remedies in view of the large stakes involved.

The study has shown that a severe restriction of grazing area had a surprisingly small effect on milk yield per cow but resulted in a marked increase in yield per unit area of pasture. The suggested explanation for this is that the restricted cows used available grass more efficiently. Since there is no evidence that they utilized the ingested grass better for milk production than the unrestricted cows—rather the reverse appears to be the case—the conclusion is forced that their greater effort was due to their harvesting proportionately more of the herbage allotted to them. It will be noted that they obtained almost as much nutrient as the cows allowed to graze an area 66% greater. This achievement was possible through more time being spent in grazing, illustrating the capacity of dairy cows to adapt themselves to adverse conditions and obtain an intake level approaching their physiological requirements.

The practical implications of this experiment are important and pose many problems. Economy of milk production obviously depends to a marked degree on the full utilization of the herbage grown. A stocking rate even relatively as high as one milking cow per acre has resulted here in an estimated minimum invisible wastage amounting to 35% of all the herbage actually available. This study suggests that much of this wastage can be avoided by the obvious and easy technique of increasing the stocking rate with consequent gain in output per acre. High stocking rate, however, is associated with several potential dangers:

(a) Herbage yield may decrease because of close grazing and frequent defoliation with the consequent long-term harmful effect on the sward.

(b) The net efficiency of the ingested herbage may fall because the total liveweight maintenance charge per unit area increases.

(c) A greater stress may be placed upon animals so handled with consequent effects upon longevity.

(d) Greater capital investment in stock and buildings is necessary, more labour is required so that per cow overhead costs may increase.

Since so much of the Ruakura work of recent years has pointed to this dominating influence of stocking rate on the efficiency of conversion of grass to all animal products—milk, meat and wool—these problems must continue to occupy the attention of serious workers in the field.

References

HANCOCK, J. (1952): *Proc. 6th Int. Grassland Cong.*, p. 1399.

———— (1954): *Dept. Agric. Anim. Res. Divis. Pub. No. 63* (reprinted from *N.Z. J. Sci. Tech.*).

WALLACE, L. R. (1956): *Proc. 7th Int. Grassland Cong.*, p. 134.

———— (1957): *Proc. Ruakura Farmers' Conf.*, p. 166.

DISCUSSION

Q: : *Dr. McMeekan previously maintained that this was an experiment in applied genetics and that it was not valid to consider some of the aspects which he has discussed today. What makes this work now valid? How does Dr. McMeekan reconcile these results with his failure to find any difference between strip and paddock grazing?*

A: : This experiment was the first at Ruakura which pointed to the dominating influence of stocking rate upon production per acre. Since it was not primarily designed to this end and since its implications in this regard could be very far reaching in its effects upon farming methods, we were frankly frightened to draw undue attention to these aspects at the time. Since then, our initial reluctance has been overcome as many other experimental studies with both cattle and sheep have confirmed the basic principles involved.

With reference to the strip grazing part of the question, I see no conflict. Mr. Ian Lucas of the Rowett Research Institute, who has been working at Ruakura this season, will shortly publish the results of our final series of studies on strip versus paddock grazing—studies which incorporate stocking rate as a variable.

Q: : *How far does bulkiness of pasture, particularly in times of low dry matter content, limit intake? Was there any decrease in pasture quality associated with higher stocking rates?*

A: : I am of the opinion that the high water content of pasture of milking quality is probably the most important factor limiting intake of a dairy cow under *ad lib.* free grazing conditions. This view is reinforced by L. R. Wallace's data on intake over the season which, in general terms, shows intake to increase from spring to summer as the water content declines. From observation, pasture stocked at the higher rate on the average carried herbage in a younger, more leafy condition, so that rather than quality being inferior it was probably higher. Some confirmation of this exists from studies of the three swards. Digestibility was highest on the 'C' type pastures.

DR. A. T. JOHNS : : From results obtained at Grasslands where cows in stalls were fed red clover it appeared that intake was related to dry matter content. Intake increased up to the level of 22 to 24% dry matter and decreased at levels above this. It seemed as though it was not merely water limiting pasture intake but rather protein content which may have exerted its effects through the degree of foaming present in the rumen.

DR. MCMEEKAN : : I hope I did not imply in my answer to the previous question that the water content was the only factor limiting pasture intake of dairy cows.

Q : : *In interpreting the results of these experiments attention should be paid to the following points: The high proportion of two-year old animals; the weights of the treatment groups were similar when the experiment began but differed at the end; and the proportion of fresh animals brought into the experiment in the second and third seasons was high. Would Dr. McMeekan have expected a result of such magnitude in favour of group 'C' in terms of production per acre had cows approximating to normal herd age composition been used over a longer term?*

A : : If interest is fixed on the absolute differences, I do not know the answer yet. I hope to get an answer from the re-designed No. 2 Experiment where a comparably high stocking rate is being used with a herd of normal age distribution and over a long period of time. From the results to date, I would not expect any real difference due to age composition on a short-term basis. If, however, the interest is, as it should be, fixed upon the relative differences, then I do not consider the age composition of the cattle concerned comes into the picture.

Q : : *Would Dr. McMeekan comment on the economics of concentrate feeding of the animals stocked at the higher rate?*

A : : Because feeding of concentrates at the level used over the whole lactation was completely uneconomic I have not been interested in speculating as to what might have happened had they been used also at a higher stocking rate.

DR. JOHN HAMMOND : : I would like to make two comments. I would agree with Dr. McMeekan that it is the water content that limits pasture intake and mention that in experiments in Britain it has been found that the removal of water from silage can give greater dry matter intakes. The effect of concentrates on milk production cannot be judged on their immediate effect; thus it has been found in Britain that if additional feed is given at the peak of lactation this is reflected not only in greater milk yields at the time of feeding concentrates, but also in a lower decline in the lactation curve after the peak.