S. Afr. J. Anim. Sci. 5, 143–148 (1975)

PRINCIPLES AND PRACTICE IN LEVEL OF FEEDING FOR THE DAIRY COW

W.H. Broster
National Institute for Research in Dairying, Shinfield, Reading, Berks, England

Food is the most expensive item in milking production. Level of feeding of the cow is therefore a critical issue for the farmer, how much supplementary concentrates to give and when to give them. In this paper the basic principles of the problem and their interpretation in practice will be discussed. For brevity only key references are given to literature sources. The emphasis will be on the practical vision of the problem of how much to give the cow.

Approach to feeding the dairy cow

The classical approach to feeding the dairy cow has been to estimate the amount of food a cow needs on a particular day from the amount of milk she is giving on that day. To do this coefficient for the nutritive value of the foods to hand and the efficiency of conversion of food to milk are employed. Live mass and milk composition can be variously added into the calculation. The approach has been broadened beyond the concept of meeting the cow's requirements for protein and energy day by day. This latter system has a number of limitations from both managerial and nutritional points of view (Blaxter 1956, 1962). Thus from the animal aspect the role of liveweight change in milk production is not considered; a constant efficiency of food utilization by one cow at different levels of intake is assumed and also by different cows; each day is reckoned of equal merit; and the economics of the exercise are ignored. Such systems nevertheless provided a better basis than traditional time honoured ideas.

In effect, with the classical approach, the amount of milk dictates the ration and there is in the exercise almost an element of duty to meet requirements. At favourable price ratios of food to milk the procedure works well. The rub comes when food prices outstrip milk prices by far and the farmer becomes very forcibly aware that profit is not catered for. He has an apparent dilemma: to feel according to requirements and possibly lose money; or to cut food and take the consequences.

In practice of course there has been an element of deception in the application of the concept of feeding according to requirements. The cow can buffer out some variation in food intake and errors in estimating food values and intakes. It takes time for the effects of different levels of intake to appear. The cow's yield fluctuates a little naturally day by day and is gradually altering all the time as she goes through lactation. To the casual look all can appear well even if it is not. Added to this is the artifact that if rations are faithfully calculated at regular intervals according to current yield then a check on the feeding based on the same ratio as used in the original computation will appear to justify the feeding level chosen. For example a cow gives 20 kg milk per day over several months whilst being fed 4 kg concentrates per 10 kg milk. Her average daily intake is a maintenance allowance plus 8 kg concentrates. Set against a yield of 20 kg milk per day she appears to give 10 kg milk per 4 kg concentrates. This is a purely circuitous argument and proves only that the system was carefully applied. The dramatic effects from a change from deficiency to excess that such a calculation implies just do not occur. The cow's response to change in intake level is much more subtle. She goes on living quite happily on a whole range of intakes. Thus cows calving in the autumn in Britain with a yield potential of 500 kg milk in the lactation will merit 1 000 kg concentrates in addition to a good forage feeding programme. In fact the on-farm range of intakes will be 500–1 500 kg. Some of this will be attributed to variation in forage allowance and quality but much will reflect the practical man's attitude to requirements. He may feel he can 'get away' with little of such foods, or that it does not pay to give them; on the other hand he may feel that generous feeding 'brings the best out of the cow' and that must be profitable. Take another example: in New Zealand spring calving is the most common practice. The price of concentrates compared with that of milk prohibits almost totally the use of concentrates. Admittedly other factors come in here but the point made is that price is a dominant factor.

It is therefore critical to find out just what does happen when intakes vary from the 'requirement' levels. That is a very complicated problem, fascinating to the nutritionist working in this field and absolutely basic to the dairy farmer. I am well aware of the contributions to a solution by Van der Merwe and Elliott, and have been encouraged by their thinking.

In South Africa, efforts towards improved feeding and the interest in forage quality have been noted (Bonsma & Landrey, 1968; Louw, 1969; Basson & van Rensburg 1972). All focus attention on feeding levels. How much reliance should be placed on forage? How far in the intensive commercial unit can the individual cow be catered for? The keynote is the question of how the cow responds to the level of feeding she is given.

Economist's point of view

The economist appreciates this point. He sees level of milk production as a response to the level of intake. Changes in milk output with change of ration can lead to estimates of the optimum intake for a given cow in a given price situation. Extra food is set against the extra milk it produces. This is a response. This gives a broader basis for feeding, allowing for the effect of variation in intake on output, for whilst one can say that a cow will give 25 kg milk on a certain intake, the wider issue is that some cows will give 25 kg milk

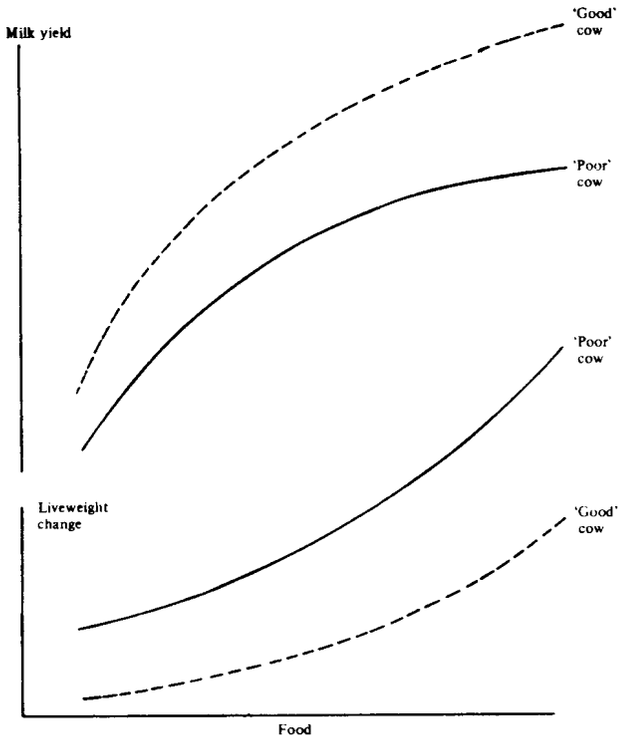

Fig. 1. *Change in daily milk yield and in liveweight gain of 'good' and 'poor' dairy cows with change in intake of food. The 'good' cow emphasizes milk at the expense of body tissue.*

if overfed whilst others will give 25 kg when underfed, and yet others will never give 25 kg. So the best level of feeding has to be decided for each of these categories of cow. And equally it is not true to say that the '25 kg' cow must have, never fail, that certain amount of food just to get that 25 kg milk. It may not pay.

Thus in the recent protein supply crisis the question basically was 'What will happen if the protein supply is less than ideal?' Broster and Smith (1973) reported that a fall in yield would occur of 0,45 kg milk per 0,1 kg digestible crude protein deficiency, accompanied by a small fall in rate of liveweight gain. This provides a yardstick for the farmer to decide the level of protein he is prepared to provide in a given price situation. Note that the *farmer* decides the level of feeding, not the cow's yield. The whole concept of feeding now becomes more dynamic and capable of meeting factors of supply, environment, and management.

Objectives in studying level of intake for the dairy cow

It is therefore essential to measure change of yield with change of ration. It is necessary to do this stage by stage of the lactation cycle because the cow follows a natural pattern of milk production. It is furthermore necessary to consider the whole lactation, and indeed the whole lifetime of the cow to see if any long term effects of good or bad feeding accumulate over periods of time. This latter point brings in liveweight and body condition plus such factors as fertility and seasonal variation in food supply. It is the link between the scientific appraisal of nutrient requirement (A.R.C. 1965) and practical wisdom such as 'steaming-up' and 'lead feeding' which I shall deal with later.

The immediate effect of level of feeding

Broster (1969, 1972) and Broster and Clough (1974) have discussed the use of concentrates as the marginal input factor, i.e. the one the farmer normally varies in a forage based diet. Responses are therefore expressed in terms of concentrates added to a basic ration of forages. At low levels of intake the effect of concentrates is large. The effect of extra amounts decrease as the total supply increases; the law of diminishing returns applies (Fig. 1). For a cow giving 20 kg milk on a reasonable ration the average size of response is 1,5 kg milk per 1 kg change in starch equivalent intake. This response should be compared with the normal rate of feeding for all milk of 1 kg concentrates per 2,5 kg milk produced. The marginal response is much the lower. This is not all however, though it is frequently all that is quoted. The extra milk is accompanied by an increase of 0,15% S.N.F. and 0,15 kg liveweight gain/day (Boster, & Smith, 1969). So extra food benefits milk yield, milk composition and body condition. And conversely when the cow is underfed she loses body condition, a point rarely commented on but, as will be seen, of vital importance. This rate of response is such that relatively small deviations from requirements would go unnoticed – both for over- and for underfeeding – until food prices become critical relative to milk prices.

The optimal level of intake in economic terms is that at which the final allowance of food produces an amount of milk of equal monetary value to itself, If milk is cheap relative to concentrates then level of feeding must be reduced and vice versa. Evidence is available (Burt, 1957; Broster,1974) to assist the farmer in making decisions. The average value I quoted needs documenting for a variety of conditions. I propose to deal with two here: the quality of cow, and the lactation cycle.

Effect of quality of cow

The higher yielding cow has a better response (Fig. 1), of the order of an extra 0,1 kg milk per extra kg concentrates, for every extra 1 kg milk produced on the basal ration. What constitutes a 'good' cow, here meaning a dairy-type cow, or a 'bad' cow, here meaning a beef-type cow? In this respect there are 2 factors so far as plane of nutrition is concerned. The beef-type cow will eat less and she will devote more of each kg she consumes to meat and less to milk than will the dairy cow. Note the importance placed on direction of food partition rather than on total efficiency of food conversion. The divergence between these main types of cow is of course well known, but it is also apparent amongst dairy cows themselves. Within a group, the cow that gives a lot of milk from a given amount of food will give proportionately less body gain. It is

pointless to try and raise the potential of the 'poor' cow by overfeeding; equally it is wrong to lose potential by underfeeding the 'good' cow. This partition is also seen in the individual cow's performance as she passes through lactation – as time from calving increases so the milk yield potential decreased and so also the live weight potential increases. In other words the cow becomes relatively more beef cow-like in her food utilisation as she approaches the end of lactation.

A problem still not totally resolved is the relationship between maximum food intake and level of yield capacity. Many hold the view that the high yielding cow eats more than the low yielding cow. The famous '10 gallon' American cow "Lorna" however ate only enough food for 25 kg milk daily, producing a further 25 kg per day from body reserves. The cow "Quantum" at N.I.R.D. gave 45 kg milk and consumed 28 kg of air-dried food equal to 4,7% of her weight per day during experiments conducted by J.A. Bines.

There is a vital distinction to be grasped here. On the one hand there is the point that on a given amount of food the more the milk produced by a cow the less the liveweight gain that is made. On the other hand if the food allowance is increased for the individual cow she divides the extra between milk and body gain. So there are two points: firstly the effect of milk potential and secondly the effect of level of feeding.

Liveweight change becomes the extra factor to be considered in food utilisation after level of intake, milk yield potential and stage of lactation. However it is not just a question of over-fed cows getting fat. The broader pattern of food x milk x body reserves is seen in the working of the lactation cycle.

The lactation cycle

Too much attention has been given to the current milking situation, and not enough to the overall output story – over the lactation and over the lifetime of the cow (Swart & van der Merwe, 1962). This pattern of day-by-day performance must be built into total lactation performance. The effect of variation in food intake over *whole* lactations is greater (15%) than would be expected if judged from the effect observed in mid-lactation alone (Burt, 1957). This in effect is saying that *the whole lactation,* not the day-by-day output, is the unit of milk production that must be considered, and the contributions of the various phases need to be examined.

The progress of daily milk yield over the lactation is well known. An early lactation phase of increasing milk yield per day is followed by a plateau of peak yield of about three weeks. Thereafter yield falls over the long mid- and late-lactation period. This is typical of U.K. cows (Fig. 2). Voluntary food intake rises from a low level around calving to a peak intake rate which is delayed until *after* the occurrence of peak yield. Thereafter intake remains high until late pregnancy (Cowan, Oliver & Elliott, 1970).

Live weight shows a reverse pattern to milk. It falls initially, then stabilizes and begins to recover as yield of milk falls. The key point is that the patterns

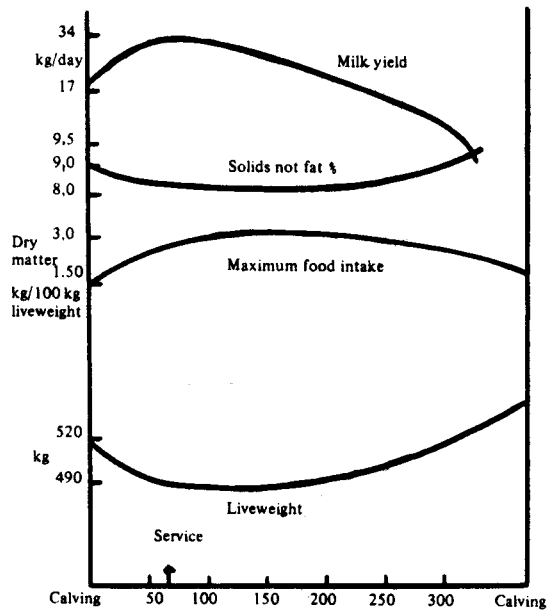

Fig. 2 *The course of daily milk yield, solids-not-fat content, liveweight and appetite of the dairy cow over the lactation cycle*

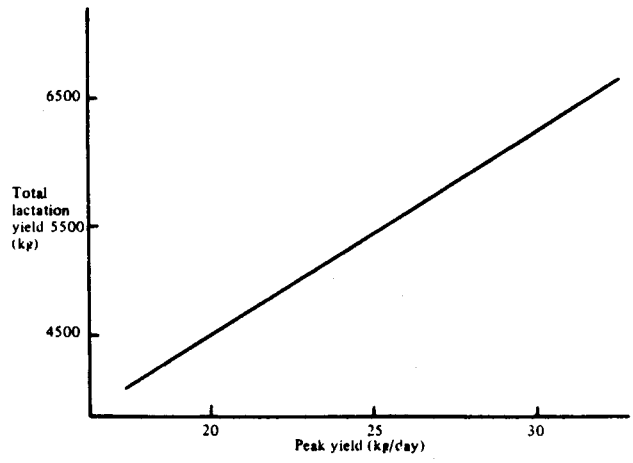

Fig. 3 *The relationship between peak yield of milk per day and total lactation output, for variation in peak yield due to genetic, nutritional or health factors*

of milk live weight are inter-related and are affected by level of feeding. Thus in early lactation there is a potential gap between maximum yield and maximum intake. The cow can meet this situation by drawing on such body reserves as she has available to help her meet udder demands for nutrients. If those reserves are not available then she cannot withdraw them and milk yield suffers. There appears to be a limit, it should be noted, to which body reserves can be withdrawn, without the cow becoming ill.

Importance of peak yield

A fall in yield in early lactation is critical to total lactation performance: for each 1 kg fall in daily yield at peak of production total lactation yield is

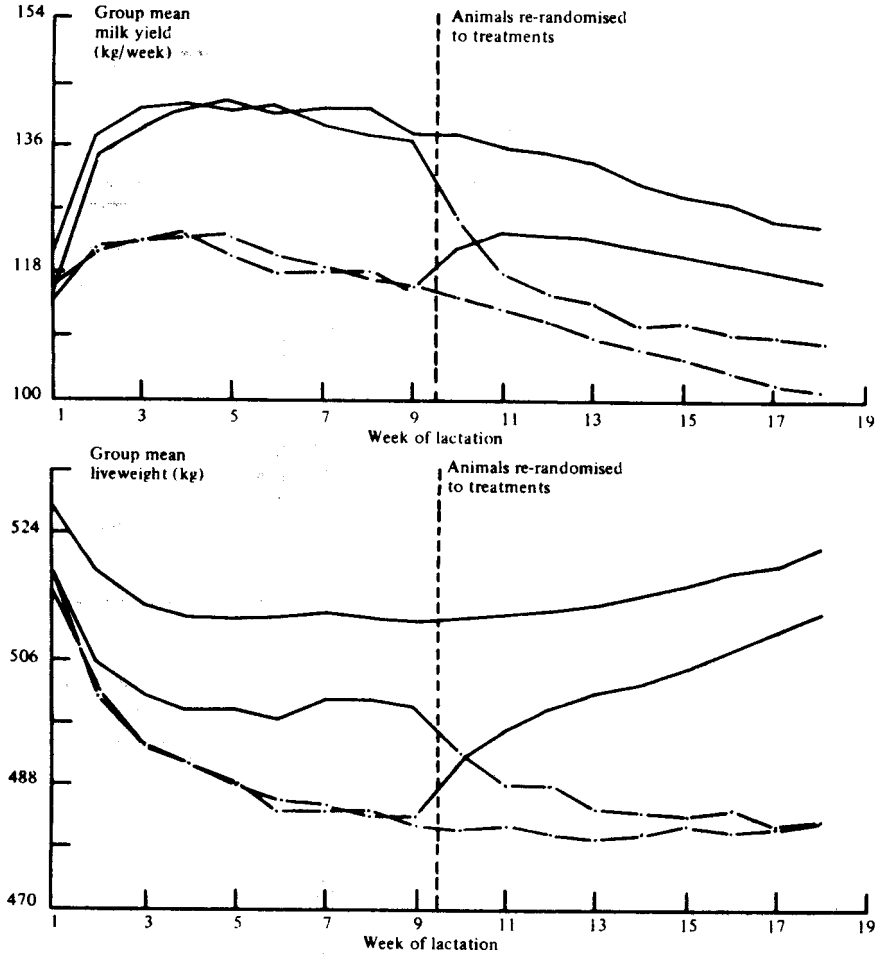

Fig. 4 *The results for milk yield and liveweight of an experiment (Broster* et al. *1969) with two fixed levels of intake in early and in mid lactation. The graphs show that in early lactation the cow attempts to offset low food intake by drawing on body reserves; that the effect of extra food on milk yield is greater in early than in mid lactation; and that level of feeding in early lactation affects use of food in mid lactation – more generous feeding after calving favours milk production in mid lactation at the expense of body reserves. (High intake ———; Low intake –·–·–)*

likely to fall by 150 kg (Fig. 3). In the U.K. some 15% of total lactation yield is involved here. This is a nutritional effect on the individual cow performance which mirrors the parallel effect of genetic merit. The reason appears to be that in early lactation the cow is establishing her level of production for the whole of the cycle; if, for whatever reason (dystochia, vitamin deficiency, hypomagnesaemia for example, apart from feeding) her potential is not maximized in early lactation she will effectively have a reduced milk output potential for the whole lactation. This means that she will be that much more inclined to produce body reserves in mid-lactation than milk as demonstrated by Broster *et al.* (1969) (Fig. 4). So attempts to remedy a poor performance in early lactation by more generous feeding in mid-lactation are going to be more expensive, if indeed they are feasible. There is a residual significance from plane of nutrition around calving affecting the day-by-day performance of the cow over the whole of the rest of lactation.

Importance of pre-calving feeding

Peak yield is affected by both pre- and post-calving feeding levels (Broster, 1971); they contribute jointly to the achievement of maximum peak yield but neither can raise peak yield above the innate potential. The best guide to feeding in the dry period is the cow's body condition. This should be sufficiently good at calving to provide the body reserves to be mobilized in early lactation. As the foetus gains at about 0,3 kg/day it follows that the dam must gain at least this rate in late pregnancy in order to maintain, let alone increase, her body condition. The pressure on late pregnancy feeding to get the cow in good body condition depends in turn on feeding in the previous mid- and late-lactation and the dry period. Thus, gains in body reserves at these times are effectively preparation for the next lactation. Hence the well known farm practice of generous feeding in late pregnancy or 'steaming up' – not, as many think, to increase potential but to guarantee it will be fully exploited.

Intake in early lactation

It may be argued that the problematical low intake after calving (Fig. 2) may be met by diets rich in concentrates and with highly nutritious forages. Obviously the highly nutritious forages are advantageous. There is evidence however that a diet of 80% concentrates and the remainder of roughage may in fact reduce the potential withdrawal of body reserves (Amir, 1972). This is controversial; Broster *et al.* (1975) did not find this effect. What is apparent is that large doses of concentrates at this time can cause digestive upsets, far-reaching in their effects on total lactation output. Judiciously generous concentrates allowances in early lactation are recommended however and are described as 'lead feeding'. Thus it is established that the horizons in feeding the dairy cow must embrace more than her current requirements and indeed more than the economics of the current situation. Early lactation can be described as the development period of potential.

Mid-lactation

In mid-lactation live weight stabilizes; thereafter gain in live weight and recovery of body reserves begin as daily milk yield gradually falls. There is some evidence that conception rate may be related to rate of liveweight gain at this time and hence plane of nutrition (Van Rensburg, 1974). This is a most important aspect of long term nutrition which will need thorough documentation (Broster, 1973) such as is not yet available. Variation in level of feeding at this time has less effect on current milk yield and dramatically less effect on total output over the whole lactation than level of feeding in early lactation (Fig. 4). The high yielder appears to benefit more from extension of generous feeding into mid-lactation than does the low yielder. But the milk yield potential of the cow is declining and there is no advantage in attempting to induce artificially high persistency of milk production by overgenerous feeding.

Persistency of yield

Much attention is given to rates of fall of milk yield in mid-lactation. The yield of the high producing cow falls more rapidly week by week than that of the low yielding cow, though percentage-wise the fall rate does not differ very markedly for high compared with low yielding cows (Fig. 4). Of course the cow with a naturally high persistency is a better animal than the one with low persistency. Heifers fall in yield less rapidly than cows. Variation in persistency accounts for only 10–15% of total variation in output. Pregnancy reduces yield from about the 24th week onwards. The long mid-lactation is the phase of exploitation of potential set up after calving.

And so to the dry period. Feeding in preparation for the subsequent lactation has already been mentioned. There are several other points. A period without milking should intervene between lactations (Wheelock & Dodd, 1969). Eight weeks is regarded as minimal for this. A calving interval of less than 360 days leads to a fall in yield in the subsequent lactation (Wood, 1970) but extension of the calving interval beyond this does not markedly improve yield. Late lactation and the dry period are times for recovery from the effects of the lactation and preparation for the next one.

Multi-lactation effects

Logically the study of food utilisation over a single lactation needs to be extended to cover several lactations – indeed the lifetime of the cow. This is not easily done. The available evidence suggests that the adverse effects of underfeeding for a period may require a whole lactation for their elimination and that the benefits from generous feeding accumulate from one lactation to the next until the full potential of the animal is exploited after which no further benefit is then derived.

Plane of nutrition and milk composition

SNF content of the milk responds to plane of nutrition very much like milk yield. Fat content of the milk may be benefitted from long term feeding but by-and-large is dependent on other factors in the diet than plane of nutrition *per se* (Broster *et al.* 1969; Storry, 1970).

Practical application

The application of these principles on the farm does not depend purely on precision calibration. Pressure is on the farmer to expedite feeding in combination with other aspects of his dairy unit. The advantages of reducing labour costs need to be set against the advantages of precision feeding. Roughages are usually fed to cows in groups, concentrates to cows individually only in the milking parlour and then by volume not weight. Provided the general plane of nutrition is adequate the benefits of individual feeding must give way to group feeding of cows (Broster & Clough, 1974). *Ad libitum* feeding of a series of complete diets, equalized feeding of all animals, self-feeding of silage are all interpretations of this theme with varying degrees of error from the nutritional point of view, which should be set against their merits managerially speaking.

Broster & Clough (1974) have studied the problems of feeding cows in the totally mechanized unit. They argue that the principles of nutrition can be divided into key issues which must be observed and secondary less vital issues that can be dealt with more summarily. Good body condition at calving is essential. Identification of yield potential shortly after calving is also essential. These features ensure that the ration fed at peak is appropriate. Thereafter mid-lactation feeding can be more stereotyped, but always with the economics and the general feeding policy of the herd over the lactation in mind, because at this time the objective is exploitation of the potential previously set up. Broster

& Clough (1974) have described a system of wall-charts which can be based on predicted total milk output per day from the herd, to plot what yield may be expected from the herd at any one date, together with the actual yield. Anomalous situations exposed by the charts for whole herd or for individuals can then be examined immediately they appear, not retrospectively as is so frequently the case. The farmer can then take action forthwith to avert the problem. We have called this 'management by anomaly'.

Breeding and nutrition

Regarding evaluation of breeding merit of dairy stock, there is need to consider both efficiency of food utilisation and the partition of nutrients to milk and body reserves as well as gross yield and milk composition. There is indeed need to consider performance at more than one level of intake. Furthermore in such studies it is necessary to have a measure of independence of food intake and yield.

Conclusion

In this discussion the concept of responses to plane of nutrition has been advanced as a focal point in deciding level of feeding for the dairy cow. These responses, embracing milk yield and composition, live-mass change, and fertility are influenced by yield potential and stage of lactation of the animal. All these factors can be integrated to formulate an optimal level of intake for a particular cow. This does not exclude the concept of nutrient requirements as generally understood but indicates that such a concept has a broader and more dynamic approach, including economic appraisal, than the simple, but narrow, one of nutrients apparently required according to milk yield on a particular day.

Acknowledgement

I should like to thank Mrs V.J. Broster and Mr. T. Smith for helpful discussions in preparing this paper.

References

AGRICULTURAL RESEARCH COUNCIL (1965). *Nutrient Requirements of Farm Livestock No. 2 Ruminants.* Technical Reviews & Summaries. London: H.M.S.O.

AMIR, S. (1974). Roughage concentrate ratio in the diet of dairy cows. Paper to The Stockmen's School, San Antonio, Texas, Jan. 7–10, 1974.

BASSON, W.D. & VAN RENSBURG, W.J.J. (1972). Feeding of dairy cattle. The contribution of maintenance requirements to feeding costs. *Milk Producer* (South Africa) March 1972, p. 10 & p. 15.

BLAXTER, K.L. (1956). Starch equivalents ration standards and milk production. Proc. Br. Soc. Anim. Prod. 1956, 1–31.

BLAXTER, K.L. (1962). *Energy Metabolism of Ruminants,* 1st edn. London: Hutchinson.

BONSMA, F.N. & LANDREY, J. (1968). Dairy production in South Africa. *Proc. S. Afr. Soc. Anim. Prod.* 7, 41.

BROSTER, W.H. (1969). Proc. 3rd Nutrition Conf. Fd Manufacturers, University of Nottingham, 53. Eds. H. Swan & D. Lewis. London: J. & A. Churchill.

BROSTER, W.H. (1971). The effect on milk yield of the cow of the level of feeding before calving. *Dairy Sci. Abstr.* 33, 253.

BROSTER, W.H. (1972). Effect on milk yield of the cow of the level of feeding during lactation. *Dairy Sci. Abstr.* 34, 265.

BROSTER, W.H. (1973). Liveweight change and fertility in the lactating dairy cow. A Review. *Vet. Rec.* 93, 417.

BROSTER, W.H. (1974). Response of the dairy cow to level of feeding. *Bien. Rev. natn. Inst. Res. Dairy,* 14.

BROSTER, W.H., BROSTER, V.J. & SMITH, T. (1969). Experiments on the nutrition of dairy heifer. VIII Effect on milk production of level of feedings at two stages of the lactation. *J. agric. Sci., Camb.* 72, 229.

BROSTER, W.H., BROSTER, V.J., SMITH, T. & SIVITER, J.W. (1975). Experiments on the nutrition of the dairy heifer. 9. Food utilization in lactation. *J. agric. Sci., Camb.* 84, 173.

BROSTER, W.H. & CLOUGH, P.A. (1974) Feeding the cow on the large farm unit. *Wld Rev. Anim. Prod.* 9, 22.

BROSTER, W.H. & SMITH, T. (1973) How to survive the protein crisis. *Dairy Farmer, Ipswich,* 20 (10), 49.

BURT, A.W.A. (1957) The influence of level of feeding during lactation upon the yield and composition of milk. *Dairy Sci. Abstr.* 19, 435.

COWAN, E.D., OLIVER, J. & ELLIOTT, R.C. (1970) Complete diets for dairy cows. *Rhod. J. agric. Res.* 8, 15–22; 23; 33.

LOUW, G.N. (1969) The nutritive value of natural grazings in South Africa. *Proc. S. Afr. Soc. Anim. Prod.* 8, 57.

STORRY, J.E. (1970). Reviews of the progress of dairy Science. Section A, Physiology: Ruminant metabolism in relation to the synthesis and secretion of milk fat. *J. Dairy Res.* 37, 139.

SWART, J.C. & VAN DER MERWE, F.J. (1962). Efficiency in Dairy Cattle. *Proc. S. Afr. Soc. Anim. Prod.* 1, 46.

VAN RENSBURG, S.W.J. (1974). Why that long inter calving period? *Milk Producer* (South Africa) March 1974, p. 6, 7 & 9.

WHEELOCK, J.V. & DODD, F.H. (1969). Non-nutritional factors affecting milk yield in dairy cattle. *J. Dairy Res.* 36, 379.

WOOD, P.D.P. (1970). Private Communication. Milk Marketing Board of England and Wales.