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THE EFFICIENCY OF FEED UTILIZATION

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SUMMARY

The importance of digestibility is discussed in relation to the efficiency with which feed is used for maintenance, growth and lactation. Several managerial factors which influence the efficiency of pasture utilization are reviewed—stocking rate and the complementary roles of adjusting pasture production to stock feed requirements and of adjusting stock management to seasonal pasture growth. Selection of animals for efficient feed conversion is shown to be of great importance.

IN THE SEARCH for ever-increasing levels of farm production it is probable that, at least in the immediate future, the most potent force available will be to increase the total amount of feed grown. But as more is learned about the factors which influence the utilization of this feed, and as farmers become more skilled in pasture and animal management, so the animal factor may well become the more important.

The principles governing increases in animal production have been outlined by C. P. McMeekan and the Ruakura school as increasing:

(1) The amount of grass grown,
(2) The percentage of this grass actually eaten by the animal,
(3) The efficiency of utilization of the feed eaten,

and this is a good starting point.

The first is, however, not within the scope of this paper and has been considered in earlier papers in this symposium. The second is governed primarily by stocking rate and will be discussed briefly while the third—the efficiency of utilization—will form the major theme of this paper.

STOCKING RATE

Of the factors which influence the percentage of feed grown actually eaten by the animals, one is the managerial efficiency with which current pasture growth and current stock requirements are equated so that there are no periods of luxury consumption, and a second is the stocking rate or carrying capacity. The former is also relevant to utilization and will be discussed later. This brings stocking rate immediately to the fore.

The work done by C. P. McMeekan, F. E. T. Suckling, D. E. Walker, L. R. Wallace, J. B. Hutton and more recently by the Department of Agriculture at Waimate West, Tangoio and Waerenga-o-kuri has shown that high stocking rate gives higher production per acre, primarily, it is thought, through a greater percentage of the feed grown being actually consumed by the stock because of the higher grazing pressure. It may in part be complicated by pasture-animal interactions. As stocking rate increases, individual performance may decline but production per acre increases; however, maximum profit per acre is reached at a stage before maximum production. What more, then, needs to be done? As stocking rate offers the simplest and most rapid method of increasing production and efficiency of production, this topic warrants continued emphasis. To be more specific the following suggestions are ventured:

(1) Theoretically, increasing stocking rate must break at some point. The writer is aware of only one trial where the breaking point has been determined.

(2) In some of the trials, there have been insufficient numbers of stocking rates to permit determination of maximum production rate and optimum economic rate.

(3) No worthwhile stocking rate trials have been done in the South Island or the dry east coast areas of the North Island where the problems of high stocking rate are different from those at Ruakura, Te Awa, etc.

(4) Lastly, and most importantly, the farmer and farm adviser want to know how to tell whether or not a farm is understocked or overstocked and where the optimum lies. This requires a knowledge of certain fundamental criteria of performance, such as optimum liveweight, fleece weight, mortality rate. These are not known, partly because trials have not been designed with this intent and partly because it re-

quires reaching and passing the breaking point. This is a most important need and it cannot be met solely by trials at Ruakura or any one centre, for the criteria will probably differ in different environments.

This leads to the major theme of this paper—the efficiency of utilization of the feed consumed.

THE IMPORTANCE OF DIGESTIBILITY

One of the first aspects to consider is the fundamental influence of feed quality on feed utilization. Since the major determinant of animal production is energy, feed quality in this context will be defined as the percentage of metabolizable energy (M.E.), digestible energy (D.E.) or more simply digestible organic matter (D.O.M.).

As digestibility increases in a series of foodstuffs, a chain reaction ensues. Increasing digestibility means that a bigger proportion of the food is absorbed and since digestion is more complete it is also more rapid. This facilitates the ingestion of more food and also encourages a more desirable fermentation, one which produces a lower proportion of the lowest and energetically least useful volatile fatty acid—acetic acid—and higher proportions of the higher and more useful acids—propionic and butyric. Up to digestibilities of 60 to 70%, increasing digestibility induces increasing D.M. intake, increasing percentage utilization and a better V.F.A. ratio. Above about 70%, another mechanism interposes which limits the advantage to the last two—the better percentage utilization and V.F.A. ratio.

The influence which digestibility and its resultant V.F.A. ratio has on the percentage efficiency of utilization of the absorbed energy is shown in Fig. 1, adopted from Blaxter and other sources. It will be seen from this that the efficiency with which animals use energy for maintenance is relatively independent of the type of foodstuff, for fat synthesis (lipogenesis) the energy from highly digestible foods is much more efficiently used because it has a low acetic acid proportion, while for lactation an optimum exists at about 70 to 80% digestibility of O.M. or a molar acetic acid value of 60%. For growth of young stock the situation is not known but is probably between the maintenance and lipogenesis lines and has been inserted as a dotted line.

Several very significant deductions of practical importance may be made from these graphs. For example, roughages are efficiently used for maintenance but inefficiently used in production rations. A growing fattening animal must have feeds of high digestibility. Livestock enterprises in which maintenance is a high proportion of cost should employ a D.O.M. system of food evaluation instead of the system of starch equivalents. An implica-

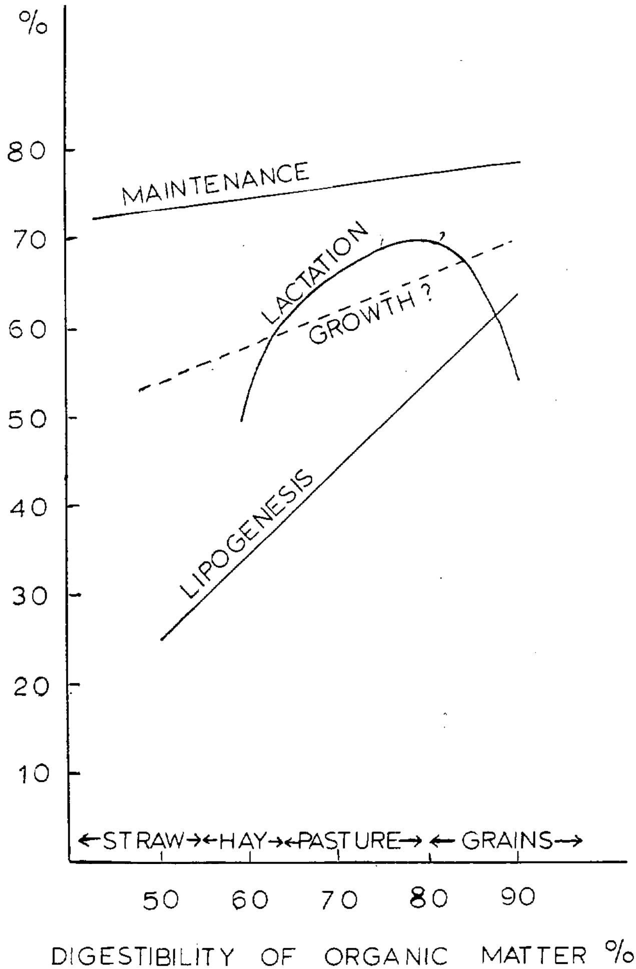

Fig. 1: The effect of digestibility on the efficiency of utilization of digestible organic matter (D.O.M.) for various functions.

tion one can draw from the figure is the principle that the efficiency of feed utilization is at a maximum when the feed eaten exactly equals the feed requirement. Consider the alternatives of (1) exactly maintaining a sheep at, say, 120 lb liveweight, (2) allowing it to increase to 130 lb and then reducing to 120 lb, or (3) decreasing to 110 lb and regaining to 120 lb. Suppose the feed has 60% O.M. digestibility. If the ewe is maintained, exactly, on this feed the feed will be used with 74% efficiency. If the animal uses the feed for fat deposition, it will be used with only 35% efficiency during the deposition period but the energy so deposited will subsequently be used with 100% efficiency for maintenance. Overall the continuous maintenance treatment is considerably more efficient. So, quite apart from any critical time relationships, it is more efficient to meet current needs exactly than it is to allow body fat to buffer the needs.

If the contribution of digestibility *per se.* is added to Fig. 1 and one includes the influence of digestibility on the efficiency of utilization of O.M. or D.M. then results are obtained as shown in Fig. 2. This again emphasizes the supreme importance of digestibility, of growing pasture of high digestibility, and of consuming it when its digestibility is high. It also illustrates that different types of production are not equally sensitive to digestibility, so the animal producer must not only have sufficient feed available but in certain critical times of the year the quality or digestibility is also critical. It is important to know these.

FEED REQUIREMENTS OF STOCK

It is necessary to know what are the feed requirements of stock in all the varying types and conditions met with in practice. The feeding standards of today have been derived from experiments conducted in Europe and North America with animals fed known amounts of feed. In order to feed known amounts, the experimental animals have been housed and fed in pens or stalls. To the minimum requirements so determined, a little has been added for luck to give the recommended standards and it has been assumed that these apply in the field.

With the development of techniques for measuring the intake of the free-grazing animal, it has been possible to check the validity of this assumption. The technique most commonly used is the chromic oxide-nitrogen method which, like all others, is an indirect one. With this technique Wallace and Hutton at Ruakura working with dairy cows, and Lambourne, Hill, Drew and Coop with sheep have shown that the intakes of the grazing animal are very significantly higher than those of housed animals. This view was originally contested by U.K. workers but more recent experiments are tending to confirm the New Zealand view. The increased requirement for dairy cows is of the order of 20% which appears on partitioning by multiple regression analysis to be mainly in the maintenance requirement, while that for sheep is

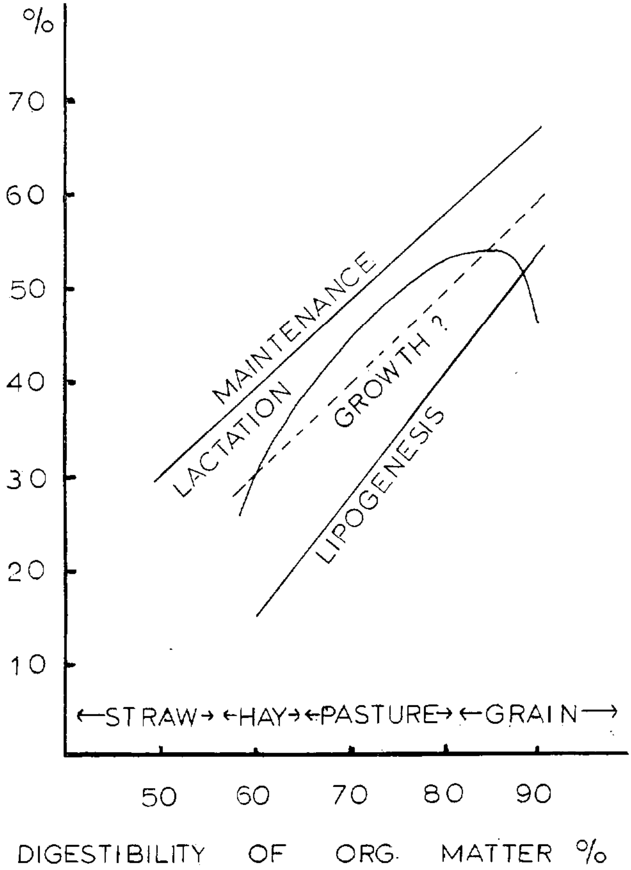

Fig. 2: The effect of digestibility on the efficiency of utilization of dry matter (D.M.) for various purposes.

round 20 to 60%, again mostly in the maintenance requirement and dependent on climatic conditions and the availability of the grass.

It seems that these increased costs incurred by the grazing animal are of sufficient magnitude to warrant further work to develop more direct techniques of intake measurement, such as through oxygen consumption rather than through faecal output.

The other important deduction from this work is that the causes of the increased requirement should be identified and if possible eliminated. Calorimetric work by Blaxter and Joyce, Graham and others has suggested that the actual energy cost of walking and grazing by the sheep is only about 10 to 15% under reasonable conditions, but that the extra heat loss due to wind and rain could account for quite substantial increases, especially in sheep with short fleece lengths, and this has been confirmed in a rough practical trial at Lincoln (Coop, unpubl.). The comparable effects of grazing and climate on cattle are not known.

Clearly, the factors and their significance in causing the increased grazing requirement need to be known. Once known, new management techniques to minimize them may be developed, for example, by restricting grazing area and increasing grass availability, improved shelter, modification of shearing methods to leave more wool on the sheep. In the ultimate, zero-grazing or systems such as the haylage system of farming largely offset these energy costs of grazing though they do substitute other costs. For these reasons the haylage system should not be condemned out of hand. There is certainly not the evidence to support the system, but neither can it be certain that it has as little to offer as some people think.

ADJUSTING PASTURE PRODUCTION TO FEED REQUIREMENT

A contrast exists between feed requirement and pasture production. Feed requirement is difficult to measure but easy to forecast whereas pasture production is relatively easy to measure but difficult to forecast, especially in areas of unreliable rainfall.

Adjustment of pasture production and other forms of feed supply to stock requirement is a well recognized principle which has long been emphasized. It is an extremely important aspect of production, and research is being conducted in many places.

The conservation of excess spring-summer growth as hay or silage is widely practised. So, too, is the saving of surplus autumn growth as autumn-saved pasture or winter-saved pasture. Also many forage crops are grown throughout the summer and autumn, and special-purpose pastures such as H1 and Italian ryegrass, and Western Wolths, all as means of conserving surplus growing potential of summer and autumn into the relatively deficient periods of winter and early spring.

Lastly pasture supply can be adjusted by grazing management and fertilizer application.

To some degree these methods are competitive but in the main they are alternatives and various combinations can be used. It is not proposed to take these matters further here, not because they are not very important, but rather because this field of work is being investigated fairly thoroughly by D.S.I.R. and the Department of Agriculture.

The use of concentrates, especially barley grain, or any other cheap grain for livestock feeding in New Zealand deserves comment. New Zealand is probably passing out of the phase of feed supply where concentrates were dismissed out of hand as being too expensive in comparison with grass or hay. First, the costs of hay and silage making have gone up more rapidly than those of barley, and, secondly, it has been shown that barley can be easily and sucessfully used as a ration for sheep and cattle. On a cost basis, barley remains uncompetitive with grazing. Where barley does seem to have a place and is likely to have an increasing place, is as the safety margin for high stocking rate on sheep farms, on the one hand, and as a means of compensating for low voluntary intake of pasture-fed dairy cattle in early lactation, on the other, as suggested by Hutton. It is uneconomic to feed sheep barley for the production it produces, but if, by having barley stored and available, farmers are more easily convinced that the extra ewe or half ewe per acre can be carried, then the profit from the extra sheep more than offsets the cost of the barley. Barley as a cheap grain also comes into its own as the basic fattening feed for finishing beef cattle.

ADJUSTING STOCK MANAGEMENT TO FEED SUPPLY

The scientist in animal research anxious to produce quick results for the farmer is plagued by a host of homeostatic mechanisms possessed by animals highly useful to the animal and a discouragement to the scientist. This is the resilience of the animal, its ability to adjust its production to its intake, its ability to make compensatory growth, and so on. An alternative, therefore, to adjusting feed to the stock is to adjust the stock to the feed. This inevitably happens to some degree, or it can be quite deliberate.

The first possibility is to allow the stock to gain or lose weight. This is equivalent to the conservation of excess summer or autumn growth not as hay or autumn-saved pasture but as fat on the animal's back. Very little is known about this. In the case of the ewe, it is known that there are relatively critical and non-critical times of the year. For example, the last few weeks of pregnancy, and the grass-eating phase of the young lamb (from, say, 4 weeks of age to weaning) are critical, the flushing period is mildly critical, and the rest of the year is relatively not critical. It is certain that a *laissez-faire* system will fall down on these points, but, in terms of labour input, or output of animal product per labour unit, this system may not be as bad as is often thought. The experiments of set-stocking versus rotational grazing at Tangoio and Waerenga-o-kuri suggest that perhaps the value of so-called good management is over-estimated and it is good that cherished ideas are submitted to the test. There are aspects of this which should be explored. Is energy stored as fat as efficiently used for maintenance and lactation as the energy in food? The writer endeavoured to point out earlier by calculation that it was not as efficient and further there are undoubted metabolic hazards in converting body fat into foetal growth and possibly also to milk. Nevertheless, the losses associated with this system may be less than those in converting surplus growth into hay or of saving it as standing hay or autumn-saved pasture for use some months later. For, in an economy based on more stock and less labour, it may be economic to sacrifice a few nutritional principles.

A second method of adjusting stock requirement is by various ratios of wet and dry stock, and by varying calving, lambing and weaning dates. The optimum lambing or calving date changes with developments according to whether the ability to grow or conserve feed means that the winter or the summer drought is the limiting factor. A recent development which facilitates the efficiency of feed utilization is synchronized mating and lambing whereby, having a concentrated and predictable lambing, better use is made of flushing feed and pre-lambing feed.

Allied to lambing, calving and weaning dates are age and weight at slaughter. With sheep there is little doubt that, in regard to efficiency, most lambs in New Zealand are slaughtered too early. Part of this is associated with the desire to avoid overfatness of meat but, provided the market will permit some decline in conformation, the sooner use is made of the faster growing later maturing export lamb sires the better, thus taking the average New Zealand lamb to 34 lb instead of 30 lb. An even better way of increasing efficiency and of achieving a better fit of seasonal pasture production and flock requirement is to increase the lambing percentage to 200%, a ewe with twins in fact producing a much better agreement between the two than a ewe with a single lamb. Quite apart from this better fit, a twin-bearing ewe is more efficient than a single-bearing ewe by 50% for meat production and 30% for meat plus wool production. The possibility also exists with twice-a-year lambing of a 120% spring lambing and 80% autumn lambing. This may be feasible in areas with reliable autumn growth and a short winter, such as in Northland, Auckland and west coast areas of the North Island, but in the South Island one 200% lambing would be more attractive and efficient.

Beef cattle requirements are the most difficult to fit to pasture growth because, unlike lambs, cattle are not slaughtered at the end of their first summer. The winter feed requirement of a ewe flock is about 40% of maximum summer requirement, whereas for the beef herd the winter requirement is about 55%. Hence, every effort must be made to slaughter stock other than breeding cows after one winter only, which means at 18 to 20 months, and this means growing them sufficiently rapidly that they reach reasonable carcass weights at this age.

PHYSIOLOGICAL EFFECTS

There is a very extensive overseas literature on the effect and practical usage of stilboestrol and hexoestrol implantations in fattening sheep and cattle. It undoubtedly increases liveweight gain and efficiency of feed utilization as measured by feed conversion ratio. Nearly all fattening cattle in the U.S.A. are now treated with stilboestrol. A preliminary look at this under New Zealand grazing conditions has been made both at Ruakura and Lincoln with not particularly promising results, and since the treatment is not permitted in this country there has been no outcry to alter the legislation. These steroids prolong the growth phase—that is, muscle formation and nitrogen retention—and retard the fat deposition phase in the animal—or create a faster growing but later maturing animal. Ten years ago this was not desired because the aim was to fatten the animals and the importance of conformation was much more strongly supported than it is now. With changing markets, increasing demand for lean meat, a lesser significance of conformation, and an increasing problem of the overfat animal, one can foresee that the judicious shot of stilboestrol in the ear for the potentially overfat lamb or cattle beast could solve a number of problems as well as increase the efficiency of feed utilization.

GENETIC EFFECTS

It is well recognized that significant differences in efficiency exist between different species, different breeds within a species, and different individuals of a breed. This is further influenced by the management system adopted.

Several estimations have been recorded in the literature showing that non-ruminants are more efficient than ruminants, and that among ruminants, dairy cattle are more efficient than beef cattle or sheep.

Using New Zealand data on the intake of grazing animals and applying these to the New Zealand national herd or flock—that is, including wastage and the breeding of replacements, etc.—the relative efficiencies are given in Table 1.

TABLE 1: RELATIVE EFFICIENCY OF LIVESTOCK (PERCENTAGE)

	lb Carcase Meat / lb D.O.M. intake	lb Edible Protein / Digestible Protein Intake
Broiler chickens	 26	21
Egg production	.... 18*	24
Dairy cattle	.... 18*	14
Beef cattle	.... 4.0	2.3
Sheep (meat only)	.... 3.0	2.0
Sheep (meat plus wool)†	4.8	5.7

*Calorific efficiency
†1 lb greasy wool valued as equivalent to 2 lb meat.

Perhaps more important even than these figures are management effects. For example, beef production from the weaner calf is 6.5% efficient excluding replacement if the animal is slaughtered at 2½ years of age, but 9.3% efficient if it can be slaughtered at 1½ years of age.

Individual animals of the same age and breed vary quite widely in their efficiency of conversion. This is complicated by the level of intake. The highest producers are normally the most efficient because the overhead of the daily maintenance requirement is spread over a larger amount of production. Therefore, animals which have voluntary intakes above average will be more efficient even though the actual metabolic processes within the animal do not vary in efficiency. To get the real metabolic differences in efficiency, it is necessary to feed all the animals at the same level of intake. When this is done, there are still considerable differences in metabolic efficiency differences of the order of 10% as shown by Dodsworth with growing steers, 20 to 30% as shown in beef cattle performance tests in the U.S.A., and as large as 40% as shown for wool growth at Lincoln. Fortunately, it appears that high metabolic efficiency is correlated with high voluntary intake, so that selection for high production under free-grazing conditions also causes selection for high efficiency.

Therefore, it is highly important that, along with managerial factors that contribute to high efficiency, there should be an accompanying breeding policy based on selection for high fertility, high growth rate, high fleece weight and high milk or butterfat production. Breeding, like stocking rate, is one of the crucial areas where much progress can be made.