Usefulness to the Animal Producer of Research Findings

NUTRITIONAL ASPECTS OF THE GROWTH OF GRAZING ANIMALS

J.L. Corbett*

I. INTRODUCTION

Research findings that would be of most use in practice would be those that showed how a massive increase in production could be obtained at miniscule cost. In some instances these happy circumstances have arisen from nutritional research, for example the transformation of animals wasting and dying to a state of thriving good health by use of a few cents worth of a mineral identified as deficient in the diet. It would be unwise to suppose that the days of such great leaps forward are past; it is in the nature of research that one cannot have precise foreknowledge of its outcome, otherwise it would be defenceless to the charge of intellectual hedonism. Research workers may well retain a lingering fancy that they will hit the jackpot, but have to be realists and understand, as must their sponsors, that progress is hard-won. Some results may indicate that additional inputs to a production system will be profitable; other results at least as useful can indicate where costs may be saved. Thus Hutchinson (1971) has shown that contrary to the widely held assumption that fodder conservation must increase animal production, adoption of the practice in a wool production system can in many circumstances be detrimental to sheep nutrition and performance.

Erroneous assumptions may be promoted if research into the feeding value and use of pasture is based largely on studies of plants and animals as separate entities (Willoughby 1970a). The component of a pastoral production system studied must be "a sufficiently independent part . . . so that conclusions are not made invalid by interactions . . . not studied" and it should be relevant to "some production system, actual or conceptual" (Morley and Spedding 1968). This is not to say the usefulness of the work is to be judged simply by whether the results are immediately applicable in a production system. The research worker in nutrition as in other disciplines certainly has responsibilities directly to practice, and should not be so arrogant as to suppose he is primarily an innovator who shows producers the way forward; there is much to be done in catching up on and consolidating advances made by innovative producers, who are well represented in this Society's membership. The research worker also has responsibilities at one or more removes from practice, the trendy terminology being 'strategic' or 'basic' studies compared with 'tactical' (Cmd. 4814) though it is to be hoped the overriding assessment will always be whether the research is good or bad (Howie 1971).

Biologists will often appear to be preoccupied with maximising physical outputs, which may well be a suicidal course for producers. It is necessary to explore the potentials for and limitations to production per animal and per unit area of land, though this should be in a context that allows examination of what is desirable and feasible within the biological system and in relation to economic conditions and community interests. The economist should have information that will enable him to assess whether the returns from applying the new technology are likely to be worthwhile; the producer will certainly find out and should tell.

Davidson and Martin (1965) have examined the phenomenon that production on the farm is usually less, often substantially less, than is obtained under experimental conditions. For example meat production per hectare of pasture in practice was about one-half that obtained experimentally in a similar physical environment, with similar breeds of

*CSIRO Division of Animal Production, Armidale, N.S.W. 2350.
livestock and cattle:sheep ratios, and with similar stocking rate. They concluded that the grazier is, naturally, concerned with returns on labour and capital, and because of the problems of optimizing management of individual animals and the timing of operations, especially in large-scale enterprises, the biological potential of livestock may not be fully utilized on commercial farms. In contrast, experimental studies are characterized by high labour and capital use in a relatively controlled environment with "luxury" use of many inputs. These circumstances occur most obviously in studies on animals in pens.

II. STUDIES IN PENS AND AT PASTURE

Many studies in pens are clearly relevant to intensive hand-feeding systems of animal production. A justification for such work in relation to pastoral production is that housed and grazing animals are similar biologically and it is not necessary, nor would it be practicable, to make studies in the field that were as detailed and various as those that are made on animals under restraint.

McDonald (1968) has pointed out that apart from characteristic differences between the diets of the animals in the two situations, differences in their nutritional requirements are quantitative rather than qualitative. In the pen, the environment and experimental error can be controlled very closely, but the occurrence of interactions that can be of crucial importance in practice is thereby restricted or even eliminated; the choice of the animal subsystems for study may be biologically sound but the responses observed are seldom additive in whole systems. Consequently, though effects of a treatment may be measured precisely, extrapolation of the results to the field is problematical. On the other hand, measurements on grazing animals are unlikely to have the apparent tidiness of those from the animal house but there will be less risk that they are misleading for pastoral practice or of doubtful relevance.

Pen studies are necessary because many problems encountered in the field, including those in the development of measurement techniques, can best be resolved under closely controlled conditions. The information gained must in turn be taken back into the field and used to increase understanding of processes in pastoral production.

III. PRODUCTION PER ANIMAL AND PER HECTARE

Relationships of production per head and per unit area to stocking rate have been clarified by Jones and Sandland (1974) and Sandland and Jones (1975). In retrospect it appears that the nature of these relationships had been confused by subjectivity in the use of the term 'optimum grazing pressure' (or 'optimum stocking rate'), and in the definition of an 'optimum' when results from grazing trials were examined. Some of these trials were of short duration during the main period of plant growth when the observed liveweight gains would have tended to reflect animal potential more than the productivity of the pastures, which properly must be measured over whole grazing seasons. Observed gains per animal had appeared to be more or less constant (plateau) over quite a wide range of stocking rates less than the optimum or 'critical' rate, above which they declined. Jones and Sandland (1974) have now demonstrated from results of their own experiments and many others with sheep and cattle in a wide range of environments that, for all practical purposes, the relationship between gain per head \( I_p \) and stocking rate \( X \) (animals per hectare) is essentially rectilinear without significant plateau and of the form \( Y = a - bX \) (Figure 1). The constant \( a \) represents maximum achievable gain per animal at infinitely low stocking rate, and expresses the nutritional quality of the pasture with herbage quantity non-limiting.
It follows that optimum stocking rate, defined as maximum gain per hectare \( Y_H_{\text{max}} \), occurs when gain per animal is one half of that possible \( (a/b) \). At twice the stocking rate for \( Y_H_{\text{max}} \), the gain per animal (and per hectare) is zero.

It should be noted that these relationships relate to properly controlled studies where stocking rate is the only experimental variable. A survey of beef enterprises in England made by the Meat and Livestock Commission (1970) showed that despite a four-fold variation in stocking rate among the 56 farms studied, there was no clear trend in individual animal performance (Baker 1975). In practice the intensification of animal production is associated with many changes in management, which on those 56 farms certainly included differential usage of supplementary feeds and fertilizers. It should also be noted that this discussion does not apply to wool. Sheep continue to grow wool, though slowly, when suffering undernutrition and liveweight loss, but production per hectare increases as stocking rate increases to the practicable limit (Langlands and Bennett 1973).

Optimum stocking rate is an appropriate term for the situation of greatest physical output per hectare, but not necessarily so for output in monetary terms. Maximum returns may be obtained at a substantially different stocking rate. The market or managerial problems may indicate that gain per animal should be increased at the cost of area output to finish animals soon rather than later, or stock might be purchased cheaply and low gains accepted in hope of profitable sale or seasonal improvement in feed supplies. Stocking rates will also be varied according to what is regarded as an acceptable level of risk. In any event it must surely be encouraging to the producer that whatever are established to be the appropriate levels of inputs in particular circumstances to achieve optimal gross margin, it appears (Jardine 1975) that these can be varied quite widely before gross margin is seriously affected.

Where animals are being reared for breeding, there would be a substantial improvement in nutritional efficiency if, as standard practice, sheep lambed first at one year of age and cattle calved at two years. There is much evidence that success in achieving these aims is dependent
'on liveweight at joining (Dyrmundsson 1973; Young 1974). To reach the desirable minimum liveweight the average daily gain of sheep to seven months of age has to be about 120 g, and of cattle to 15 months some 0.5 to 0.6 kg. These rates of growth can be achieved fairly readily on temperate but not on tropical pastures, and the nature and causes of such differences will now be considered.

IV. POTENTIAL PRODUCTION PER ANIMAL AND PER HECTARE

Figure 2 illustrates a number of ways in which pastures could differ in productivity. The two pastures A and C promote the same gains per head at very low stocking rate, but output per hectare is lower from C because the productivity of the individual animals decreases more rapidly as their numbers increase. This situation can obviously occur when there is a quantitative difference in herbage production; it might not be detected by mowing techniques because it is likely these would not reveal the inability of the plants to persist except under very light grazing pressure.

Pastures A and B represent a special but not improbable contrast. Numerous reports indicate that good temperate pastures can be expected to produce annual liveweight gains of around 400 kg ha\(^{-1}\). Similar production is obtained from pastures in northern N.S.W. and the east coast regions of Queensland (Norman 1974), but whereas many graziers in temperate Australia are accustomed to their cattle making average daily gains of around 0.8 kg without supplementary feed for a substantial part of the year, such rates of growth are uncommon and occur rather fleetingly on the tropical pastures. Stobbs (1975) reviewed grazing experiments in the tropics and found that daily gains per steer averaged over 12 months were 0.35 kg; even when grain was given to offset seasonal inadequacies in the pastures the gains rarely exceeded 0.6 kg.

It will be seen that pasture A has a greater stock-carrying capacity than B, and this difference also mirrors reality. It is noticeable that beef cattle stocking rates per hectare in year-long experiments on temperate pastures generally fall within, but on good tropical pastures often exceed, the range of 0.7 to 2.8 used by Hamilton and Bath (1970) in Victoria. Gains per hectare in that experiment were similar to those obtained from a subtropical grass-legume pasture by Bryan and Evans (1971) but with a range in mean annual stocking rates of 2.5 to 3.8.

The potential production from grasses such as pangola or kikuyu in the wet tropics or under irrigation is substantially greater than that from temperate pasture plants. Holmes (1968) in the UK calculated that the herbage produced with an annual application of 300 kg fertilizer N per hectare if wholly consumed by beef cattle should give 1790 kg gain ha\(^{-1}\). For New Zealand grass-legume pastures with 90% of herbage consumed Hutton (1970) calculated a gain of 1450 kg ha\(^{-1}\) was possible. Horton and Holmes (1974) have obtained 1348 and 1198 kg over 24 week periods in two successive years. This production is greater than has yet been obtained in practice where, however, it generally would be impossible to follow the experimental procedures and manage the stock and pastures with such flexibility that animal demands were always most carefully matched with herbage supplies. In contrast, there are several reports from the tropics of annual gains per hectare exceeding 1200 kg, including one report of 2760 kg (Norman 1974). As in the UK studies this production was achieved with massive fertilizer N applications (> 500 kg ha\(^{-1}\)) which were greater, and had better seasonal distribution, than the N available from fixation in the best leguminous pastures (Henzell 1968; Holmes 1968).

The nutritionist studying pastoral production must be concerned with area outputs, but has a particular responsibility to explore limitations to individual animal performance.
V. LIMITATIONS TO PRODUCTION PER ANIMAL

Graziers could wish to obtain daily gains of about 350 g from lambs and three to four times that rate for cattle. These are practicable targets in intensive hand-feeding systems, but are not obtained at pasture except briefly from suckled young or during compensatory growth after a scarcity of feed has been ameliorated by a seasonal change in climate. Compensatory growth is due mainly to enhanced voluntary feed consumption (Graham and Searle 1975), but in general the maxima for the interrelated factors of grazing intake, digestibility, and the nature and efficiency of use of the metabolites from digestion fall short of the maxima for the energy-dense rations that can be compounded for hand-feeding. In simplest terms, the greater the intake of digestible dry or organic matter (DDM, DOM) the greater will be animal gain.

(i) Herbage yield and availability Within types of pastures there is broadly a negative relationship between dry matter yield at a particular time and nutritional value. This of course is due mainly to the changes in the plant associated with maturation, but the generalisation that more means worse does apply between pasture types if, for example, temperate and tropical species are compared. Minson and McLeod (1970) found an average difference of 12.8 digestibility units in favour of the temperate species, presumably related in some way to the distinctive C_3 and C_4 pathways of photosynthesis.

Provided herbage is not completely senesced and grazing pressure is low, there is likely to be sufficient heterogeneity within a large mass of standing dry matter for the animal to select highly nutritious feed. Such feed may be classified with apparent crudity, but meaningfully, as ‘green’ compared with ‘dead’, and Hamilton et al. (1970, 1973) and others show that the digestibility of intake is positively related to yield of green herbage, and to DOM intake and lamb growth. While quantitative relations exist between the amount of herbage present and liveweight gain (e.g. Willoughby 1959) account must also be taken of availability to the animal as affected by spatial distribution over the pasture area and variation in plant morphology and canopy structure. Stobbs (1975) found that a reason for disappointing animal performance on tropical pastures is the ‘loose packing’ of the herbage which makes it difficult for animals to prehend large quantities per bite, particularly of leaf. Animals graze leaf in preference to stem and leafiness is positively related to intake within, but not between, plant species (Minson and Laredo 1972; Laredo and Minson 1975). Leaf has less mechanical strength and intake may be greater because prehension causes less physical fatigue, but a major factor is the shorter retention time in the reticulo-rumen of leaf compared with the more fibrous stem (Laredo and Minson 1973).

(ii) Digestion and metabolism Variation in ruminal retention time is probably an important underlying cause of the general relationship between the intake and apparent digestibility of feeds by ruminants, and the variation about this relationship among plant species.

A shorter retention time, which makes room for more feed more quickly; also has significant effects on the efficiency of digestive processes and on the pattern of metabolites available to the animal. The energetic efficiency of ruminal fermentation increases as turnover time decreases because maintenance requirements of the microorganisms are a lesser proportion of the energy transactions, and their growth yield (Y_ATP) will be greater (Sutherland 1976). In addition the efficiency of energy capture in fermentation products will tend to be greater because volatile fatty acids (VFA) produced from the more readily digestible feeds include a smaller proportion of acetic acid than the VFA from more fibrous, less digestible, material (Mrskov 1975). Earlier emphasis on the significance of molar proportions of ruminal VFA tended to shade the
importance of VFA quantities in relation to animal production, but theoretically the dissimilation of high propionate VFA should be more efficient and promote more animal growth than low propionate, provided the capacity of enzymic pathways to metabolize this substance is not exceeded (Mrskov 1975). This consideration will be one of several involved in the increasing efficiency of utilization of metabolizable energy by animals as its concentration in the feed increases (Greenhalgh 1975), and it might be that the use of propionate for gluconeogenesis spared use of some amino acids for this purpose.

A reduction in retention time in the rumen will, however, have a more direct effect on the efficiency of use of dietary protein because the proportion fermented will be reduced. Observed differences between pastures in animal growth may well stem partly from differences in the, proportion of OM intake including protein that is not fermented and is digested in the small intestine (MacRae and Ulyatt 1974; Corbett et al 1976). The tannins present in a number of legumes such as sainfoin (McLeod 1974) might confer on their proteins some protection from microbial degradation, and that species is known to promote rapid lamb growth. Cattle grazing high tannin plants could be at less risk from bloat, or a mild form that may cause restriction of grazing intake (Hennessy 1973).

The few per cent of 'ether extract' in herbage is often given little attention, but it should be noted that quite a small difference in the content could cause a difference at equal DOM intakes of, say, 25 g in the quantity of lipid entering the intestines of sheep. This lipid could promote an energy gain by the animal as great as that promoted by the digestion of 100 g non-lipid OM, equivalent to a difference in herbage DM intake as large as 150 to 200 g.

(iii) Amelioration by supplementary feeding Animal production is dependent primarily on the quantity of feed eaten, and a nutrient deficiency in the diet is generally manifest in a reduction in intake and production before clinical signs of the deficiency appear. The problems of identifying a deficiency state are perhaps less than those associated with its correction in the field. Simple treatments with long-term effects are available for some trace minerals (Co and Se 'bullets'; injectable Cu) but treatment of many disorders is confronted by the problem of great variation between animals in intake from licks or troughs. This problem applies to supplementations with N or energy, which have often given disappointing results. Urea is commonly given to cattle to promote greater intake of dry standing roughage with low N content (< 1% in DM), and at least to minimize liveweight losses. It might be effective whilst it is given, but with few exceptions (e.g. Winks, Alexander and Lynch 1970) longer term benefits have been small or absent because of subsequent compensatory gains by the unsupplemented animals. On the many occasions when supplementary non-protein N has been ineffective a real need of the animals for additional energy could perhaps not be satisfied because supplies of fermentable protein, not simply N, were insufficient for vigorous activity by ruminal microorganisms or, more likely, the animals' own protein status was poor and adversely affected intake (Egan 1965). Utilization of the N also depends on an adequate supply of sulphur; the dietary N:S ratio should be narrower than 15:1 but this requirement can be met from the S in molasses.

Supplementary feeding on better quality pastures causes reductions in grazing intake. Though herbage may be spared for other use, immediate effects of the supplement on liveweight gains are generally small unless grazing intake is seriously restricted by low herbage availability.

Research has defined many needs for supplementary feeding, though the nature of 'ill-thrift' syndromes and the causes of seasonal variation in the net energy value of herbage (Corbett et al 1966) are unclear.
Research has also defined many problems associated with the practice but has not yet resolved these satisfactorily.

(iv) Amelioration by management. It is well established that rotational grazing or related management has little or no effect on animal gain unless there is very highly intensive usage of pasture or the plant species are severely depressed by continuous grazing (e.g. lucerne), and subdivision of a pasture is of no benefit unless the number of stock is too large for management as one group, or close control of reproduction is desired (Willoughby 1970b). Subdivision will facilitate fodder conservation and forage cropping, but there is a restricted range of conditions under which these inputs in a pastoral production system will increase output (Willoughby 1970b; Hutchinson 1971; Bishop and Birrell 1975). The greatest economic benefits may come from opportunity sales of hay.

As already discussed, legumes usually give greater liveweight gains than grasses, barring problems from bloat, but in tropical pastures particularly, many species are difficult to maintain. There are clear differences in digestibility between grasses which are obviously important if these are grown for cutting and conservation. There is, however, evidence that even the relatively small difference in digestibility between ryegrass and cocksfoot is apparent in animal production under grazing conditions (Greenhalgh 1975), which indicates that measurements of the digestibility of grazed herbage can provide a ready index of the quality (a) of different pasture types.

(v) Role of modelling. The range of management options with sheep and/or cattle in pastoral environments is so large that there can never be comprehensive examination by direct experimentation. Resolution of this problem by computer modelling and other attributes of this technique were discussed at the 9th Biennial Conference. Models can only be as good as the information upon which they are constructed, and help to focus attention on its inadequacies. One obvious gap is the continuing uncertainty on quantitative aspects of energy transactions in grazing animals. For example, there is need to define more explicitly than as 'dry sheep equivalents' the effective biomass of sheep and cattle of various breeds, ages and physiological states; to this end the carbon dioxide entry rate technique (Corbett et al. 1971) is being applied to estimate the energy expenditures of a wide variety of grazing animals.

VI. ENVYO

My treatment of the allotted topic has been somewhat discursive for two reasons. One is that it is really an impertinence for, in Rothschild terms (Cmnd. 4814), the contractor to assert what a grand job he is doing for the customer. The second reason is that, even if possible in the space allowed, it would be a redundancy if I covered the same ground as that of the many relevant publications, including reviews. Instead I have attempted to reveal some strands in the fabric of the research, some concepts and approaches. I hope to have shown that the research, like good fabric, is utilitarian and perhaps not without some beauty, and is flexible so that it is and will remain appropriate to whatever changes in direction and complexity occur, or might occur, in practice.

In order that the results of his studies may indeed be useful, the research worker depends upon the highly professional services of extension workers and others for practical realisation. Whether the information is then used depends upon the extent to which the animal producer 'has confidence in the immediate and long term future of his enterprises, but here we are entering the spheres of sociologists, economists, and inevitably the politicians, national and international.
VII. REFERENCES


