Pasture Quality And Animal Production

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IT is perhaps better that I should admit now, rather than have it pointed out in the discussion, that the title of this talk on the relation between pasture and the animal might have been considerably curtailed. Quality in pasture has no meaning except in relation to the animal which eats that pasture—the thrift and productivity of the animal (and those terms should be given their widest meanings) must be the final criteria whereby the quality of the herbage is judged. It follows, therefore, that the title of this talk should consist of just the two words "Pasture Quality" and I shall endeavour during the next 40 minutes to give some picture of the problems inherent in that term. Needless to say my viewpoint will be that of one who is concerned primarily with the pasture aspect, but that is probably a good thing to an audience such as this, where accent is on the animal.

First of all, it is desirable to set this discussion within a framework and to that end I propose to give my definition of the ideal pasture for grazing animals—you may disagree with them heartily when your time comes.

(1) Ideally the pastures on any one farm should be capable of providing, without waste, without periods of undernutrition (except where that is actually desirable), and with minimum pasture maintenance costs, the requirements of the sheep or cattle for crude carbohydrate and protein. And when I say requirements I am thinking of high levels of production, equivalent to or better than those achieved by the top 10% of the farming population.

This ideal is of course a long way from achievement. Conservation and special fodder crops are still essential parts of our animal feeding programmes even in the most climatically favoured localities. On the other hand it is well to remember the enormous advances which have been made during the past 50 years towards all-pasture feeding. This struck me very forcibly on a recent visit to Southland, where winter keep has always been a major farming concern. Even in the thirty years that I can remember, the proportion of pasture herbage in the diet of sheep during the months of May to September appears to have increased spectacularly. It is surely significant that more and more research workers and farmers are thinking of winter feeding problems, not in terms of the grass which they can grow, but of the sheer physical capacity of the soil to carry the necessary hooves at moisture levels which are above field capacity.

(2) In addition to providing carbohydrate and protein which are the gross raw materials for the production of milk, meat, and wool, the ideal pasture must also provide those minerals and accessory food substances which are essential to animal health. They should be provided not only in sufficient amount but the individual components must be in a state of balance (conveniently undefined) within the feed.

(3) The first two conditions are positive ones—they deal with what the herbage should contain. The present one, the third, deals with the negative aspect. The individual plants which make up the total pasture should not elaborate, under any of the environmental conditions to which they are subjected in New Zealand, compounds which adversely affect the health and productivity of the grazing animal. Or perhaps it would be better to put that idea in another form. Under no condition should the total pasture herbage contain potentially harmful compounds at a level which will cause animal disorders or a decrease in production.

I should like to take these three parts of my definition of an ideal pasture and consider them in turn. The first deals with the pasture plant as an organism which is capable of producing in its leaves large amounts of carbohydrate and protein. No one plant can meet the farm's requirement for carbohydrate and protein throughout the year and, as you are all aware, it has been perhaps the major task of Grasslands Division to provide species and strains of grasses and clovers which are of high inherent merit and which when blended in a series of combinations will meet the requirement of the grazing animal month by month. As a newcomer to that Division I think I can say that very important advances have been made and are still being made towards that goal. In his paper this afternoon Sears will enlarge on the means whereby the farmer can introduce these newer plants to his farm and on the precautions which have to be taken to ensure that the pastures establish satisfactorily.

But throughout all this work we have used very crude measures of pasture quality and productivity. In the great majority of our trials we have used the production of dry matter per unit area and per unit time, supplementing it on many occasions with protein analyses. On the assumption that the mineral content of the herbage, expressed as the highly uninterpretable ash value, is between 7% and 10%, we have a fair idea, for each of the most significant pasture plants, of the percentage of dry matter due to mineral elements, to nitrogenous constituents, and to non-nitrogenous constituents.

Now while we are still at this very crude level, there is considerable evidence that the ratio of nitrogenous constituents (which are more than 80% proteins) to non-nitrogenous constituents (which are largely carbohydrate or whose carbon skeletons can be used in lieu of carbohydrates by the ruminant microflora) is unnecessarily high. At Grasslands Division, the average annual crude protein content of pastures at the 12000-14000lb. D.M. production level is about 24% with variations between 17% in summer and 35% in winter. There appears to be general agreement among animal nutritionists that these figures, except at special times of the year, are far higher than is required for efficient production of animal protein, whether that protein is laid down in muscular tissue, or secreted by the mammary gland or by the wool follicle. The excess protein is hydrolysed, deaminated, the ammonia excreted as urea and the non-nitrogenous part used for energy. Sjollema gives a series of reasons why he regards this round-about conversion process as a major cause of inefficiency in the animal grazing high protein herbage. Although I should like to see some of his conclusions supported by more critical experimental data than are presented in that paper, I believe that his general conclusions are not seriously challenged by nutritional workers. On the other hand I am inclined to view the position more charitably since our work on the importance of urea in the soil-plant complex.

One practical outcome of the recognition of protein waste in our highest production pasture plants is the oft-repeated request to Grasslands Division that they should breed a grass with a lower protein content in its leaves. Although I have no experimental backing for this statement it is my belief that such an approach to the rectification of the carbohydrate-protein balance in pasture herbage has a very slim chance of success. One part of the argument is purely speculative and runs something like this. Enzymatic activity and tissue synthesis obviously run hand in hand as cause and effect. All enzymes are proteins and indeed there is good cause to believe that all intracellular proteins have enzymatic functions. It seems to me quite unreasonable to expect a plant which consists only of leaf and root to build tissue rapidly at low leaf protein levels. You will note that I included the proviso "which consists only of leaf and root". This is substantially the situation in any high production pasture at heights up to 6in. If pasture plants are defoliated before any true or pseudo stem tissue is laid down, then it is my thesis that rapid recovery cannot be expected without concurrently high protein levels.

However, whether you agree with this speculation or not, I still think that we should not look to the plant breeder to provide a solution to the problem of improving quality through decreasing protein levels in the herbage. A much more obvious solution lies to our hand in allowing our pasture plants to grow to the stage where stem tissue (in the reproductive tillers) and pseudo stem tissue (in the vegetative tillers) is being formed at a rapid rate. Work in Great Britain over the past 30 years has shown that such tissue is lower in protein and higher in fibre than are the leaves where primary synthesis is going on. If pasture quality can indeed be sensibly improved by increasing the carbon to nitrogen ratio, the result can be achieved more rapidly and more simply through a change in management than through a long term breeding programme.

In the past there have been two serious difficulties in such a scheme: (1) the grasses which have formed the basis of our high production pastures have become unmanageably fibrous when allowed to get past the 4in.-6in. stage, and (2) the all-important clovers in the association tend to be completely overgrown and hence to disappear. Plant breeding work at Grasslands Division has, we believe, largely obviated these difficulties; the first through the introduction of Short Rotation Ryegrass which retains its palatability to advanced stages of growth, even past the flowering stage; the second through marked improvement in the growth characteristics and hence competitive ability of the bred strains of white and red clover. I am therefore highly interested in certain collaborative trials with Massey College Dairy Farm and with a few local farmers on the performance of short-rotation—white—red pastures which are deliberately managed to increase the carbohydrate: protein ratio.

There is one rather interesting sidelight on this possibility of growing tall pastures as a normal part of farm management. We have been accustomed to thinking of the pasture association in the horizontal dimension and analysing it botanically in terms of so many pounds of ryegrass, so many pounds of clover per acre and so on. In this new situation we should add the vertical to the horizontal dimension and consider that in a 15in. pasture, the bottom 6in. are almost entirely stem and petiole, the next 3in. a mixture of stalk and leaf (mainly grass stalk and clover leaf), the next 3in. a mixture predominantly leaf of both grasses and clovers, and the final 3in. almost undiluted grass leaf. That is a purely hypothetical pasture, arbitrarily divided into certain steps from ground level; but I think that the idea is highly pertinent in view of the animal's selective grazing habits. Moreover it brings to light a type of variability in pasture composition which is often overlooked and which is very much under the control of the farmer.

In this consideration of pasture herbage as a supplier of carbohydrate and protein, there has been some attempt at both speculation and recipe, but it must be obvious to all that I have been skirting the real problems. When we talk so glibly of "carbohydrate" and "protein", what do we really mean? To take the latter first, the reported protein content of the feed, in virtually all animal nutrition studies, is nothing more than its nitrogen content multiplied by some factor between 6.0 and 6.25. In the first place some 5% to 25% of the total nitrogen of the leaf occurs not in protein but in low molecular weight, water-soluble compounds. This is perhaps not very serious since a large part of the non-protein nitrogen is present as amino acids and peptides which, for nutritional purposes, may be regarded as being equivalent to protein. On the other hand there are present, in small amounts, other nitrogenous compounds which may be insignificant nutritionally but of considerable significance in relation to the third criterion for an ideal pasture.

But leaving out of account the non-protein nitrogen fraction, the lumping together, under the generic term "protein," of the whole

complex array of individual proteins which exist in the leaf cell, has always been a source of grief to one who was once a protein chemist. To make even the crudest separation, we must distinguish between those proteins which form an integral part of the chloroplast, in which is centred the primary mechanisms involved in photosynthesis and those which form the matrix of the cytoplasm. It is virtually certain that the chloroplasts contain complex molecules of lipid, protein, chlorophyll, and perhaps other pigments. A recent report claims that a purified complex protein of this type has actually been prepared. And when this has been said there is virtually nothing more to say on the properties and characteristics of the chloroplastic proteins. We have no accurate picture of their amino acid composition, we have only the crudest ideas of the way in which the chloroplast is freed from the leaf cell in the mouth and in the rumen, we know nothing of the mechanisms whereby lipid and pigment are broken off from the protein, nor of the extent or rate of their utilisation by bacteria of the rumen. We do not even know whether the chloroplasts contain relatively simple proteins among the complex ones.

Our ignorance of the cytoplasmic proteins is perhaps one degree less, but our knowledge of their behaviour as the main protoplasmic constituent of the leaf or as a vitally important constituent of the animal's diet is vanishingly small. Of course it may be argued that the work of Chibnall, Lugg, Tristram and others has shown the biological excellence of the mixed leaf proteins and their relative lack of variability in amino acid composition from species to species. To me this argument is singularly unsatisfactory. Proteins are more than the sum of their constituent amino acids, they have physical and pharmacological effects which cannot be predicted from their constitution, and if we are in earnest about our quest for pasture quality, we must learn more about the protein fraction of the herbage.

And just to show that nitrogen metabolism studies should not be the monopoly of the plant biochemist, I should like to ask the animal physiologists a simple question. Why does the herbivore, unlike any of the omnivores thus far studied, excrete up to 15% of its urinary nitrogen as amino-nitrogen (both free and combined) and of this amino nitrogen why is it practically all in the form of the simple amino acid glycine (Bathurst)?

The lamentable tale of ignorance which I have outlined of our knowledge of leaf proteins is not quite duplicated for the carbohydrates. Sears and I discussed this matter at the first conference of this Society 11 years ago, and, as our arguments are still reasonably valid, I shall not dwell on it further.

There is, however, one group of compounds which overlaps the conventional carbohydrate and protein fractions and to which I should like to draw your attention. Those compounds are the low molecular weight, water soluble materials together with compounds such as starch and fructosan which, though they may be insoluble or of high molecular weight, are easily and rapidly hydrolysed by enzymes of plant, animal or microbiological cells. They may be conveniently grouped together under the title of the metabolic pool of the plant organism. I think that this group is of the highest significance to plant biochemist and animal nutritionist alike. In the plant it may be looked on as a reservoir of immediately available and easily transportable materials, capable of quick mobilisation to any organ which is subject to some environmental stress. In the rumen they are quickly available to the microflora (although again we are ignorant of the mechanism by which they become available) and they undoubtedly condition, in large measure, the early metabolism of ingested food.

Our knowledge of this metabolic pool of compounds is much greater than that of proteins and structural carbohydrates. Methods are available for the simple sugars, the individual amino acids both free and combined, the organic acids such as malic and citric, and a number of others, while new analytical methods are continuously being discovered. On the other hand our knowledge of their metabolism, of the enzyme systems whereby they are synthesised and degraded within the leaf is extraordinarily incomplete. Again I would stress that to answer the immediate questions which are posed by the term "pasture quality" we must endeavour to elucidate these complex metabolic processes.

Perhaps this is a good point at which to make a comment on the organisation of to-day's programme. Again and again I have used the terms "ruminant microflora" and "ruminant metabolism" and I shall continue to use them during the remainder of this paper. At Grasslands Division we are very much interested in the fate of both individual and group components of the leaf when subjected to fermentation in the rumen, and what I say on the subject serves merely as an introduction to Johns's paper this afternoon.

So much then for herbage as a source of supply of the major dietary constituents, viz., crude protein and crude carbohydrate. Let us turn next to the second criterion which I laid down for an ideal pasture, viz., that it must contain those minerals and accessory food substances which are essential to animal health. I do not propose to say anything about herbage as a source of vitamins beyond pointing out in passing the synthetic capacity of the ruminant microflora in relation to vitamins of the B group and the unique capacity of the chlorophyllous cell to synthesise carotene.

The mineral story is however at a very interesting stage, and deserves comment if only because both plant biochemist and animal nutritionist are equally and vitally interested in the role they play in plant and animal economics respectively. From the five or six mineral elements which were recognised as essential to plant and animal growth fifty years ago, the list has now been enlarged to, I think, fourteen. During this period many points of scientific and practical importance have emerged but there are two which I wish particularly to emphasise:

(1) The recognition that although an element may exist in the organism at a level of only parts per million, its essentiality is exactly the same as an element present at levels some hundreds of times higher.

(2) The concept of balance among the mineral elements; e.g., even though the root medium of a plant contains sufficient of all the nutrient elements, growth will not be optimal unless a certain, fairly flexible, balance is maintained between the various nutrient ions.

It would be fair to state that the macro- and micro-nutrient elements required for healthy growth and reproduction of both plants and animals are now reasonably well-known. Others are to be added to the list it is virtually certain that their concentration in the various tissues is below 10^{-8} and probably below 10^{-9}. But in this consideration of pasture quality as applied to the mineral elements, the real question is: How adequate is herbage as a supplier of each and all of the elements essential for animal health?

Taking the micro-elements first, the list of achievements is most impressive. The requirements of the animal and the plant for iodine, copper, cobalt, iron, manganese, zinc, boron and molybdenum have been made clear, the deficiency symptons associated with lack of each have been described, methods for their quantitative determination have been worked out, and great increases in farming efficiency have

resulted. But it would be a rash person indeed who would say that so far as the micro-elements are concerned we know all the answers. Gross deficiencies for plant and animal may be diagnosed by soil, plant, or animal analyses. The same can be said of sufficiency, although due to the perennial problem of availability, with less certainty. But between sufficiency on the one hand and gross deficiency on the other there is a no-man's land of great scientific and economic importance in which much uncertainty exists. The limits of that no-man's land will undoubtedly be brought closer togethe by present methods of attack on the problem, but I am convinced that its continued existence is assured until we know a great deal more of their mode of action in plant and animal cells and of the enzyme systems they activate. With the emergence of that knowledge, there will undoubtedly emerge new and much more precise diagnostic methods for both plant and animal tissues.

From my reading of the literature I think it only fair to say that, during this period of intense interest in the micro-elements the plant investigators have pursued their studies of the macro-elements much more actively than did their animal colleagues. If my observation is correct, there are a number of possible reasons, not least being the economic one. To take New Zealand farmers as an example, they are spending between £8 and £10 million per year on phosphatic fertilizers primarily for pasture plant nutrition and only secondarily for animal nutrition. It is hardly surprising that the role of phosphorus in the soil-plant complex is being more intensively studied than is its place in the plant-animal complex.

But I am by no means happy about the macro-element aspect of pasture quality. The view is quite widely held that in general the calcium, phosphorus, magnesium, sodium, potassium, and sulphur levels in high production herbage are considerably above the accepted standards for livestock rations (at least in those cases where standards exist). It is argued further that the changes in concentration, both absolutely and relatively, which occur in herbage throughout the year can be dealt with quite satisfactorily by the grazing animal. I have always doubted this, and was very interested to come across a recent article by Hignett and Hignett on the effect on bovine fertility of changing calcium to phosphorus ratios at levels considerably above the accepted minima. I also cannot help being impressed by the two long-existent and still unsolved problems of milk fever and grass staggers which give support to the idea that the whole story of the macro-elements has not been told. The available evidence (and that is somewhat scanty) points to a sufficiency of calcium and magnesium in the pastures on which these disorders occur, yet nobody can deny there is some direct connection between pasture quality and incidence.

Sjollema makes a case for a reconsideration of the macro-elements on the question of the balances which should be maintained among them. Certainly in this regard potassium would bear a good deal of scrutiny. It is present in the herbage in concentrations up to nearly 4% of the dry matter so that an animal eating 30lb. per day will consume over 1lb., of which about 75% is absorbed into the blood stream and excreted by the kidneys. But the requirements of the animal for potassium are small, and one cannot help wondering what effect this large influx of potassium ion will have on the behaviour of other cations in the blood stream.

Of one thing I am convinced. Although none of us like embarking on the tedious and expensive business of masses of routine analyses, we still know far too little of the variations which occur in pastures of different botanical composition, of different heights and at different times of the year. I suspect that there are a number of similar questions to which the animal physiologist might apply himself.

The third criterion of pasture quality was that under no condition should the total pasture herbage contain harmful compounds at levels which will cause animal disorders or a decrease in animal production. Perhaps more than any other this is a matter which is causing grave concern at Grasslands Division. A frequent criticism of our improved strains of grasses and clovers is that with their introduction and proper management, the incidence of the so-called metabolic disorders increases. I have already mentioned two in milk fever and grass staggers, but to them must be added bloat, lack of thrift in hoggets, scouring from causes other than copper deficiency (direct or induced), facial eczema, ketosis, the abnormalities in certain sexual characteristics due to plant oestrogens, and probably a number of others. If this criticism is justified, and I for one am prepared to accept it with only minor qualifications, then obviously it is of major concern to plant breeder, plant biochemist and pasture ecologist alike.

Now it must be recognised that the causes of these varied disorders cannot be attributed to a group of compounds with some basic chemical similarity, or have anything in common other than that they are directly or indirectly attributable to pasture. Obviously from what has already been said the mineral elements are implicated, while we have no reason to suppose that the proteins and structural carbohydrates are blameless. Nevertheless I have to admit to some bias in favour of low molecular weight materials if only because of the striking increase in numbers of such compounds, which, during the past 20 years, have been shown to possess high pharmacological activity. Moreover we have two prototype materials in our most valuable pasture species, the cyanogenetic glucoside, lotaustralin, in white clover, and the alkaloid, perloline, in perennial ryegrass. Despite the best efforts of a numbr of members of this audience, neither has been shown to be implicated in any of the disorders mentioned, but both fall into the low molecular weight group and both, at sufficiently high levels, would undoubtedly cause grave trouble in stock. Added attraction is that with both these prototypes an immediate call could be made to the plant breeder to remedy the condition. Corkill has already bred a white clover of high agronomic merit and containing no glucoside, while the variability in perloline content of individual ryegrass plants makes it virtually certain that breeding methods would markedly lower the concentration in commercial lines.

In any case, regardless of the actual compounds or groups of compounds which may be responsible, there can be no doubt that wastage occurs in our animal populations due to lack of fulfilment of our third criterion. Fortunately for me, there are two papers in this programme which deal with specific metabolic disorders, viz, bloat and facial eczema respectively, and these papers will present two quite different methods of attacking such problems. Hence I can confine myself to some generalisations.

Under certain undefined environmental conditions the synthetic pattern of the plant changes, so that either new compounds which are harmful to animals are fabricated or that compounds which are normally present at low concentrations are elaborated to considerably higher levels. We do not know what these componds are, and hence cannot even speculate on their precursors in the metabolic pool within the plant, or the enzyme systems which are responsible for their synthesis. Equally there is no means of determining the role of ruminant fermentation in the problem. It is quite conceivable that abnormal fermentation of a relatively harmless material could lead to a metabolite which is harmful to the animal. The field is one which calls for intensive efforts by both plant and animal investigators, as few problems are of as great urgency for the farmer.

Now some attempt must be made at integration and summary of the random and widely diffused statements which have been made in

this paper. What follows is entirely my own interpretation of the problems involved and is not to be regarded as the Grasslands Division party line to which all my research officers subscribe. In the leaves of our pasture plants there is being synthesised, through the primary photosynthetic reaction which is peculiar to the chlorophyllous cell and through secondary synthetic reactions most of which are probably common to all cells, be they plant, animal or bacterial, a whole host of chemical compounds. For a few of these we have adequate analytical procedures, for a few more we can obtain a rough estimate of their concentration, and for the great majority we have no procedures at all. Indeed for this great majority we do not even know their identity. Yet these same chemical compounds, transmuted first by microbiological enzymes in the rumen, and later by tissue enzymes in the animal body, appear as our chief articles for sale in the markets of the world as meat, cheese, wool and butter.

We know from evidence provided by those compounds for which analyses are available that changes in environment can bring about large changes in the concentration of certain metabolites. We suspect that in times of environmental stress, the plant metabolic pool is drawn on for the synthesis of compounds which do not appear under normal conditions and which are quite definitely bad for the animal economy. The basic question surely is: what are the environmental factors, both internal and external, which determine the pattern of synthetic reactions which go on in a pasture plant. Of that tiny part of the sun's energy which, through excitation of chlorophyll molecules, enables reduction first of water and subsequently of carbon dioxide, how much will appear as chemical energy in protein, how much in structural elements—cellulose, polyuronides and lignin—and how much in the water soluble compounds such as sugars, amino acids, organic acids and the like which have been referred to as the metabolic pool. For a leaf of any particular physiological age, how is the balance among these groups of compounds and within these groups altered by changes in light intensity, light duration, temperature, water supply and nutrient supply. The really fundamental question surely relates to the flow of radiant energy in sunlight into chemical energy in the form of reduced carbon compounds and the alternative paths along which the first products of photosynthesis may be further metabolised. It must never be forgotten that from this flow the plant derives the energy for its growth and reproductive processes, for the absorption of nutrient ions from the soil and for the transport of minerals and metabolites; nor that the whole of the animal kingdom is completely dependent on it for its existence.

These are **not** academic meanderings. When the plant physiologist and biochemist can give some of the answers to those questions, w would be nearer an answer to the question implicit in McMeekan's recent statement to an Institute of Chemistry Conference: "The observation of the Ruakura nutritional team that dairy cows are apparently incapable of attaining adequate intakes of digestible dry matter when given **ad lib** access to autumn saved or early spring pasture of high digestibility and nutritive value when measured by current standards, yet find no difficulty in doing so later in the year on relatively sparse pastures of lower quality, will bear more than a little thought". We would also be able to answer a number of other questions of equal practical urgency, and Mitchell, in the next paper, will give more detailed information of the way in which he is tackling such problems.

Nor would it be out of place to stress again that we know very little about the fate of the products of leaf synthesis, whether "normal" or "abnormal", when subjected to ruminant fermentation; about the ability of the rumen to pass on directly or indirectly to the blood

stream, from ingesta of markedly variable chemical composition, metabolites which the animal organism can efficiently transform into those products which are the prime interest not only of this Society, but of every person in New Zealand.

In this audience there are representatives of a large number of scientific disciplines and sub-disciplines: there are pathologists, parasitologists, animal nutritionists, animal biochemists, microbiologists, plant physiologists, plant biochemists, geneticists, sheep and cow husbandmen, pasture ecologists, and probably many more. Each believes that in his hands is the key to increased production of animal products and with each and every one I entirely agree. Always provided that they recognise that the locks which their respective keys will fit are fabricated from the compounds which are produced in the leaves of our pasture plants.

REFERENCES:

Bathhurst, N. O. (1952).—J. Agr. Sc. **42** : 476.
Hignett, S. L., and Hignett, P. G. (1951).—Vet. Rec. **63** : 603.
McMeekan, C. P. (1952).—J.N.Z. Inst. Chem. **16** : 18.
Sjollema, B. (1950).—J. Brit. Grassl. Soc. **5** : 179.
Sjollema, B. (1951).—Landbk. Tijdschr. **63** : 615.

Discussion

Dr. McMEEKAN: I would question whether Hignett's data on cow fertility should be used as an argument for re-investigating the calcium and phosphorus levels in pasture herbage.

Dr. MELVILLE: Hignett's paper was quoted more as an illustration of a re-awakened interest in the macro elements.

Mr. GERRING: Is there any evidence that a high protein to carbohydrate ratio is harmful to animals. If pasture is allowed to grow tall, what effect it would have on digestibility.

Dr. MELVILLE: I know of no evidence that food protein levels of the order mentioned in the paper had any harmful effects. Digestibility goes down as the leaf to stem ratio decreases, but results from Grasslands Division indicate that loss in digestibility is amply compensated by extra bulk of herbage.