lowered and its place is taken by potassium; there is also a diminution of the volume secreted. How far this finding applies to other secretions is not known but economy in sodium is certainly made as regards its supply to the rumen.

The principal point I wish to emphasize is that the digestive system of cattle demands a considerable turnover of the animal's resources owing to its capacity and the nature of the events inside it. A study of the rates of turnover of body constituents such as water, sodium, other mineral elements and nitrogen under various circumstances may help in the end to understand why occasionally things go wrong.

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The application of recent scientific information through the feeding-stuffs industry

By J. K. D. Dow, *Food Research Department, Unilever Limited, Colworth House, Sharnbrook, Bedford*

In the early days of scientific feeding the daily diet of ruminants was thought of as a whole, much as rations for monogastric animals are regarded today. Kühn (1892–3) popularized the view already held in Germany by other workers that for convenience of practical rationing the daily diet might be considered as consisting of a portion for the maintenance of an animal in normal health, made up mainly of roughages, and a portion for the production of milk, made up of more concentrated feeds. This concept proved so convenient that it has become the standard basis of theoretical rationing. The need for maximum use of home-grown feeds, which developed in 1940, and the subsequent economic controversy about the best use of roughages and concentrates for the most economic milk yields, has tended to give the impression that two schools of dairy nutritional thought have developed: one which advocates maximum use of home-grown feeds, and the other which supports highest yields by the optimum use of concentrates. It is perhaps remarkable that the protagonists of both views advance them in the cause of maximum profitability for the farmer.

The truth is that the feeding-stuffs industry in recent years has increasingly held the view that dairy concentrates, whether purchased or home-grown, are complementary to roughages, not antagonistic, and, if the papers in this Symposium have anything in common, they tacitly agree that the underlying biochemistry of digestion of roughages and concentrates forms a complexly interwoven and fluid pattern, in which each profoundly affects the other and neither can be justifiably considered in isolation. The scientific wheel turns full circle and we are learning again that Kühn's suggestion was made only for convenience of practical rationing.

To implement this conception of the balanced concentrate as a supplement, the industry is seriously studying the most recent nutritional developments with a view to their earliest possible application.

It is frequently not appreciated, however, that a finding from a nutritional laboratory can rarely be applied before industry solves a number of development problems, and it may be of help to more fundamental workers to realize what these are. The industry may manufacture yearly, at a conservative estimate, 10 million tons of feed, so that 1% of any new ingredient calls for a supply of 100 000 tons a year. This quantity may be purchased at home or bought forward in pipe-line shipments from abroad. In either event it will be the subject of precise specification covering purity, tolerances, and the amalgam of scientific, legal and business points that go to make up contract buying. To increase efficiency of buying and formulation, it will be fitted into the linear programming of all other ingredients and, if highly priced, will be repeatedly checked for value, purity and stability before manufacture. During manufacture the physical form is important, e.g. finely divided particles are subject to loss unless suitably premixed, do not lend themselves to homogeneous mixing, and present dust hazards to workers. These problems must be solved. If ultimately the daily dose theoretically formulated is to reach the animal, premixes must also be chemically compatible and withstand grinding speeds of 18 000 ft/min and cubing temperatures of 49–77°. An example will illustrate the point.

Vitamin A has long been used in calf feeds as a result of extensive fundamental studies. The industry has been given vital information on growth responses with minimum supplementation, on blood-serum, liver, milk and faecal-excretion levels, on intestinal absorption, on the influence of heat and particle size on biological availability, and on analytical methods for determining potency in pure form. What industry has had to do, however, is to decide whether to use the natural vitamins occurring in fish-liver oils or the synthetic material supplied as emulsions, protected by wax or, more recently, gelatin coating. After selecting the form of the vitamin, it is necessary to make practical farm mixes under conditions of normal manufacture. This operation involves assaying potency at premixing, making 5-ton batch mixes and check-sampling them by chemical methods suitable for assaying the vitamin in mixed feeds, and assaying potency in the cubing plant, after mass bag handling in the factory and at weekly intervals under farm-type storage up to a shelf life of 6 months. Finally, the chemical assays must be reinforced by biological tests. This control can be worth to the industry more than £125 000 annually on a saving of only 3d./ton. The necessity for this routine is why large companies maintain their own research facilities and why the smallest country mill must have access to an analytical laboratory. The problem which may thus seem to have been

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solved at bench level often requires further extensive investigation before it can be given effect in practice.

It is not practicable to comment on the possible application through the industry of the many points raised in this Symposium, but a few questions may stimulate discussion.

Perhaps the most important problem in ruminant nutrition is finding adequate cheap energy of the desired type; silages in particular are frequently short of sugars. It has been suggested that about 70% of the total energy requirement of a ruminant is obtained from fatty acids absorbed from the reticulo-rumen. The metabolism of these acids is dictated largely by rate of absorption, which in turn depends on rumen concentration. Rook (1959) has shown that this concentration may be influenced by the chemical balances of the initial diet, and hence we reach the interesting stage of being on the threshhold of dictating, probably within the animal's inherited endocrine capacity, the metabolism connected with milk production, not only in quantity, but in quality as measured by fat and non-fatty solids content and the conditions of clinical and subclinical ketosis. Undoubtedly there are many more instances of unexpected low milk yield associated with the latter condition than are generally realized.

We are now beginning to get at the chemical background of why practical stockmen place such value on a starch supplement with silage feeds. They may not be simply 'balancing' the protein content in chemical terms, but may be regulating the animal's biochemical metabolism through its intermediate microfloral metabolism. In the meantime, there is urgent need for more work on the correlation between data obtained from chemical analyses and true values obtained by biological tests.

In the protein field the importance of the rate of evolution of ammonia in the rumen, first reported by McDonald (1948), has been stressed by Chalmers & Synge (1954), who suggest that differences in temperature of processing might have a significant effect on the nutritive value of proteins. Further, they suggest that the same proteins processed at high or low temperatures may be best used by ruminant or monogastric animals respectively. This suggestion is obviously of prime importance to the feeding-stuffs industry as it can process protein at between 75 and 105° under controlled conditions of time and moisture. It is necessary, however, to have a simple and rapid chemical test to relate protein processing to potential ammonia release before proteins can be classified as more suitable for ruminant or monogastric animals. Head (1959) has developed such a test and, since a dairy concentrate is usually made up of a number of protein sources, his ammonia-release curves for a range of protein materials are of great interest. My own colleagues are concerned in a full-scale experiment with dairy cattle to measure the practical effect of these observations. We are anxious to know if the marked differences in ammonia-release curves shown by Chalmers, Cuthbertson & Synge (1954) to be true in the experimental ruminant have an application with dairy concentrates. Our work is not complete, but we are wondering whether we can expect differences in milk production, either from variously heated proteins, or a range of proteins, in view of the response of animals to the quantity of ammonia which must be generated from spring grass.

If, however, the usefulness of this grass is due to simultaneously available sugars, it will not be too difficult to apply the findings of Chalmers, Cuthbertson & Synge and of Head to practical rations, and manufacturers will be able to use their proteins with discrimination.

The importance of the ammonia content of the rumen may be seen in another connexion from the work of Head & Rook (1955) in which they suggest that high ammonia content may be associated with reduced absorption of the magnesium ion. If it is so, it gives point to the high ammonia potential of young grass and to our own observations that many silages on the alkaline side of pH 4·6 may contain up to 30% of their total nitrogen in the form of volatile base nitrogen. In the absence of alternative means of damping out excess rumen ammonia, the addition of magnesium oxide to dairy rations for the prevention of hypomagnesaemia appears justified in this context.

Because supplies of minerals generally are usually adequate to meet the demands, the feeding-stuffs industry has never been slow to apply scientific information where there is reasonable evidence that the addition of a further mineral may prove of value. The demand of rumen organisms for copper and cobalt is recognized in many production diets, but further information is awaited on the observations of Burroughs, Latona, DePaul, Gerlaugh & Bethke (1951). They suggested that cellulose digestion is encouraged by the addition of minerals, and that the whole problem of roughage digestion might be clearer if we had a better knowledge of the mineral requirements of ruminal micro-organisms. The studies of Eadie (1959) and Phillipson (1959) on responses of the microflora to dietary stimuli may be of great economic significance. Replacement dairy heifers are traditionally reared with minimum concentrate supplementation, and, if these supplements can be formulated to increase the microflora digesting cellulose and pentosans, an enormous amount of money will be saved in the rearing industry. The work, incidentally, may contribute to the problem of bloat.

We are indebted to Reid (1959) for his painstaking work on bloat on red clover in New Zealand, but if the feeding-stuffs industry is to participate in this work, it must be to prevent and not to cure the condition. On Reid's evidence, the anti-foaming agent he used cannot give protection from one feed to the next without interfering with either milk quality or production; other agents, however, may do so.

Is it possible that intake of high-protein grass produces a rapid increase in proteolytic bacteria which themselves tend to be gas formers? Bloat is only one of a number of ruminant metabolic disorders which we believe stem from upsets of the normal processes of digestion. Perhaps others like ketosis, hypocalcaemia, and hypomagnesaemia have similar origins, even though they may occur in monogastric animals. In my view studies on the relationship between gut bacteria and nutrition are as necessary in the intestine of the cow and of monogastric animals, as we now recognize them to be in the rumen.

Workers at the Rowett Research Institute (Preston, 1956; Eadie & Oxford, 1957) have already contributed views on the microbiology of the transitional phase from the sucking calf to the ruminant, and studied particularly the influence of antibiotics (Preston, McLeod & Dinda, 1959). Technical advice (Preston, 1958) on the value of antibiotic supplements for the calf, however, is at variance with the present legal position, and raises the problem of translating into practice such information under these circumstances.

It should not be forgotten that the industry is composed of 3000 separate manufacturers, and competition, normally so valuable in protecting the farmer, is very keen. If reputable research workers advocate a supplement which the law denies to these manufacturers, and farmer customers demand it, there is a great temptation to supply, especially when analytical detection is difficult. This places a responsibility on research workers to consider not only the scientific interpretation of their data, but the effect of their writings when translated into practice. But do these workers have an adequate chance to observe the field application of their work?

No national compounder today would consider risking his goodwill and business by launching a new product that had not been adequately tested in field trials. He may have good, poor, or indeed no research facilities. He may depend entirely on published scientific evidence for his new formulas. But he would never think of marketing them until he had seen his new product tested on a variety of breeds and under a range of managements. Are the more fundamental workers at our research centres being accorded the same facilities? Have they, for example, generous access to N.A.A.S. husbandry farms? Is there any body with power to reimburse the farmer and to organize and co-ordinate such field testing for them, or do they have to rely on personal friendship with sympathetic farmers? Perhaps the industry can help the research workers in these contacts, and perhaps the research men can repay with advice to many manufacturers on the design and conduct of their own field trials.

I would say, in summarizing, let us not repeat the mistake of thinking that the cow lives primarily on, or for, either one of a two-part ration. We have been fortunate, as Balch (1959) pointed out, that the rumen, in spite of our treatment, has worked so efficiently and failed so rarely, and we must learn to interpret starch equivalent as short- and long-chain fatty acids with specific parts to play. Protein problems in the ruminant are mainly those of utilization rather than of the amino-acid balance of the monogastric animal, and an understanding of the nutrition of rumen microflora will yield great benefits to the host animal. Finally, research scientists and manufacturers have mutual obligations towards the farmer, and can help each other to create a more efficient industry and ensure in the end the best application of what was in the beginning the best research.

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