

number of factors may co-operate in this process. One of these factors is the recurrence of autolysis; another is the ingestion of bacteria by protozoa, which are themselves digested. A third is coprophagy and a fourth bacterial phagocytosis. The extent to which these several routes are in fact used in particular species under known dietetic conditions requires investigation.

REFERENCES

- Baker, F. (1939). *Sci. Progr. Twent. Cent.* **34**, 287.
 Baker, F. (1942). *Nature, Lond.*, **149**, 582.

Dr. A. C. Thaysen (Chemical Research Laboratory (Department of Scientific and Industrial Research), Teddington, Middlesex): How can it be explained that cellulose is, according to Kellner, equivalent to starch in food value when only one-third of its carbon is recovered during digestion in the form of organic acids? Obviously part at least of the remaining two-thirds of the carbon must be used in the production of other nutritionally important substances such as protein and fats, formed during the growth of the intestinal microflora and subsequently utilized by the host.

Dr. A. T. Phillipson gave the following reply: The output of nitrogen from the rumen in the form of bacteria cannot exceed the input of nitrogen into the rumen in the form of food. The ratio of protein to carbohydrate in grass is in the region of 1 : 4, this indicates that even if all the nitrogen of the food is converted into bacterial nitrogen the quantity of carbohydrate that is converted to other substances during the process is substantially larger. Part of the carbohydrate so digested can be stored as polysaccharide by the bacteria as Baker has shown while part is converted to volatile acid. The relative quantities of polysaccharide and volatile acid formed in this way are not known but, in formulating estimates of the probable quantities of bacteria and of any substance contained in the bacterial cell, the significance of the limiting factor, namely of the amount of nitrogen available, must be taken into account.

Chairman's Summing Up

Dr. W. R. Wooldridge (London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C.1): The subject we have been discussing today is a wide one and indeed the contributions of speakers have covered a wide range. Nevertheless, it seems to me that the breadth of the discussion could have been much greater. I am not going to try and summarize the detail of the discussion put before us, for speakers themselves have been precise, but I take this opportunity to try to place the present work in its wider setting so that we shall not get lost in immediate experimental detail and forget the very great difficulties of the problem as a whole.

There are 3 major factors concerned in the problem of "The Nutritional Role of the Microflora in the Alimentary Tract". They are the nature of the host animal itself, of the ingested material or food, and of the microflora.

The nature of the animal itself affects our problem in that the shape of the alimentary tract varies considerably within the animal kingdom,

and the location of the actual organ wherein the major activity of micro-organisms is thought to take place varies within the tract itself. In our discussions today we have been mainly concerned with ruminants. Here, as was brought out by Dr. Phillipson, we have microbial activity in a capacious organ preceding the true stomach or the enzymically active intestines. The bulk of the changes go on, therefore, in a relatively inactive organ, although we must not forget that the muscular mixing and the act of rumination play their part. We should also remember that very large quantities of saliva pass into the rumen and that this saliva, besides being enzymically active, contains moderately large quantities of alkaline bicarbonate. Some reference was made to the horse, reminding us that bacterial digestion in that species occurs in the caecum. We have had no experimental details of the processes involved apart from a reference to an analysis of the caecal contents carried out *post mortem*. The capacity of the equine caecum in relation to that of the alimentary tract is comparable with that of the rumen, and it is generally believed that micro-organisms play a part in it similar to that which they play in the rumen. This is at present little more than a belief and it seems to me that, bearing in mind the changed conditions in the caecum after the passage of food first through the stomach and then the small intestine, we may find that microbial activity there differs considerably from that within the rumen.

Considerable reference was made to the rat, but no reference has been made to carnivores and only passing reference to the omnivores, man and the pig. Yet all these animals have micro-organisms normally in the alimentary tract and it is probable that, in the course of their own growth, they will affect the nature of the alimentary contents. Some reference to man was made by Dr. Sinclair but, owing to the departure abroad of our first selected Chairman, Dr. Platt, we have missed an account of more striking changes. For instance, I gathered from an informal committee discussion that there is some evidence that the intestines of Russians, whose staple diet contains a large proportion of fibre, have become considerably enlarged in comparison with those of western Europeans. This, it was suggested, might be due to microbial activity upon cellulose. The photographs shown by Dr. Kon of varying caeca of rats kept upon different diets would seem to lend some support to this possibility of "herbivorous" man. Finally, the host animal, because of a peculiarity of species or possibly of a strain within a species, as suggested by Mr. Bacharach, may have considerable effect upon the microbial digestive processes occurring within its alimentary tract, depending upon whether it indulges in what might have been considered at first sight to be the unnatural habit of refection.

The second major factor, that of the composition of the diet, is an extremely important one when experimental work is being conducted upon animals, particularly the larger domestic animals. Not only does the diet vary from that of a pure carnivore to that of a strict herbivore, but we must remember the difficulties of providing a diet of constant composition in the large amounts required for experiments extending over long periods of time for the desired number of animals. For not only is it necessary to "acclimatize" the animal to the selected diet before the experiment begins but it is necessary also to try to avoid variations

vol. 3, 1945]

in composition of the diet during the experiment. These may arise through the use of different batches of a particular food crop, or through the occurrence of changes in composition of the same crop, such as pasture grass or hay, arising from the length of time it has grown, the season of reaping, or the conditions of storage. It is advisable in studying microbial activity to endeavour to standardize conditions likely to affect the composition of the bacterial environment, for such changes can have very marked effects on the nature of a mixed bacterial population.

And so I come to the third major condition, that arising from the nature of the micro-organisms themselves. Perhaps I might be permitted to comment that, although most of the work reported today has been comparatively satisfactory from a chemical standpoint, from the point of view of the strict bacteriologist, it has been far less satisfactory. In nearly all cases, reference to the microflora has been vague and concerned largely with very mixed populations. Today we have not endeavoured to discuss the activities of protozoa and only slight reference has been made to yeasts. It would seem advisable to me to endeavour to discover the nature of the mixed microflora and to find out something of the effect of the isolated species upon media such as exist in the rumen. Here it seems lies a possible extension of the important work carried out by Dr. Smith and the Cambridge school. If portions of rumen contents could be removed, sterilized and re-inoculated with single and mixed known cultures of previously isolated members of the microflora, useful results should be obtained that could definitely be assigned to the activity of the inoculated organisms. Furthermore, it must be remembered that not only can mixed populations of bacteria vary in type and number very readily with a change in the nature of the medium, but also the enzymic activities of a simple population may change markedly during the course of its own growth, particularly if alterations in environment occur during the logarithmic phase of growth.

Again, as emphasized by Dr. Thaysen, bacteria play their part not only in breaking down food products, but also in synthesis: In this connexion it should be remembered that the composition of the contents of the alimentary tract varies considerably in its content of bacterial bodies, the proportion being lowest at the oral end, while the faeces, at least in man, are made up, I believe, of over 80 per cent. of living and dead bacterial bodies. The utilization of bacterial bodies may obviously be an important factor in digestion.

I have not dealt specifically with the important work reported to us today, not because I do not appreciate its value, but because I felt it wise to stress the difficulties inherent in this work, particularly with larger animals. These animals are known through long years of careful husbandry to show a great individual idiosyncrasy and it would seem highly important in all this work that experiments should be made upon an adequate number of animals. Despite the financial difficulties, the application of the teachings of statistics to biological experiments remains highly important if sound deductions are to be formed. The need is to overcome the financial difficulties. I think all will agree that the work discussed today has been most interesting, highly significant and full of promise. It certainly merits the granting of every facility for its continuation under the best experimental conditions.