Further Comments on Net-energy Measurements

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Blaxter & Graham (1955) have mentioned in their paper that during the last 40 years few calorimetric experiments have been made on the net energy of feeding-stuffs for farm animals. I think that the most important reason for this is the great labour and expense involved. Construction of reliable apparatus may take a number of years and the subsequent output per worker is not high. For instance, at Copenhagen about five qualified scientists and four laboratory assistants spent some part of their time on the net-energy experiments. Working with cows our return per full-time worker, including assistants, was one value of net energy per annum. These figures, though of course they vary in different experiments, illustrate how slow and laborious is the accumulation of net-energy values. When the results are published they are unspectacular, so that it is difficult not only to find initial money but also continuing support for such work. If an experimental unit dies from poverty, and it has happened more than once, there is a long hiatus, until its successor reaches maturity after the long preliminary build-up.

The paucity of results and the great labour involved in securing them influence the attitude of workers to the figures obtained. There is a tendency to think that the necessary virtuosity of technique must ensure a high accuracy, although, as Blaxter & Graham (1955) have pointed out, this cannot be true for most difference experiments, and there are few instances where a statistical estimate of error can be made.

Obviously the cost and labour per unit of information need to be reduced. For this purpose the systematic control of error (Deighton & Hutchinson, 1940) and the use of modern automatic direct calorimeters (Ota, Garver & Ashby, 1953) may be of some value when the classical method of experiment is used. Another possibility is estimation of body composition before and after feeding the supermaintenance ration (Blaxter & Rook, 1952).

Blaxter & Graham (1955) emphasized the general confusion that exists regarding net-energy values for ruminants. With fowls the position appears to be more simple. Fraps (1946) after many determinations of net-energy values with chicks by carcass analysis concluded that the energy values of the digestible nutrients of most feeds were within 10% of that of maize meal. This consistency in his results was obtained in spite of the difficulty of making balanced rations for difference experiments with rapidly growing animals. Similarly, Deighton & Hutchinson (1940) found that the net energy per calorie of metabolizable energy for fattening cockerels was almost exactly the same for Sussex-ground oats as for white maize, despite a considerable difference (in terms of poultry nutrition) between the fibre contents of

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the two feeding-stuffs; the standard deviation of the difference between the means was 1%.

The general conclusion is that useful tables of net or productive energy can be made for fowls, and that not only are the values additive, but the heat increment per unit of metabolizable energy is roughly constant. This, of course, applies only if rations are properly balanced, but it is easy with our present knowledge to make a balanced ration for a fowl without serious qualitative deficiencies, because inadequacies of this kind are easily detected by failure to grow or development of pathological conditions. In ruminants, by contrast, rations that give a low net-energy value do not in general induce pathological effects, and growth experiments with these animals are not easy. In fact, the effects must usually be measured by energy-balance experiments with the difficulties already mentioned. I suggest that net-energy values for fowls appear additive because energy physiologists have been able to use information obtained by other workers in nutrition, whereas the ruminant values appear associative because ruminant physiologists have not had this advantage. Clearly the net-energy values for ruminants need to be made more additive and predictable than they are at present. Kellner realized the need for prediction, and correlated his values with the chemical analysis of feeding-stuffs as practised in his time. This analysis was crude and simple, whereas the composition of the digestible part of ruminant diets is complex; so it is hardly surprising that prediction is in general uncertain, as Blaxter & Graham (1955) have pointed out. With silage in particular the error is even more alarming. At Copenhagen values for samples of A.I.V. lucerne and beet-top silage, neutralized in different ways, ranged roughly from one-third to twice the value predicted from Kellner's factors (Møllgaard & Thorbek, 1941; Hansen & Thorbek, 1943). Moreover, there is doubt as to what factors should be applied for fibre correction in this instance.

One can argue with Nehring & Schiemann (1954) that these results merely show that the basal ration was unsuitable. But if this is so with the kind of mixed ration used and with the experience of this subject accumulated at Copenhagen (Møllgaard, 1923), one must conclude that even vaguely additive values cannot be obtained by the most skilful methods in use.

Since Kellner's day biochemistry has greatly developed, and we know more about the composition of ruminant diets and their digestion products. It is possible that the best way to continue his work may be to relate metabolizable energy and heat increment to the modern biochemistry of digestion. When such fundamental work is completed, the question of additive net-energy values and their prediction could be re-examined. It is already known that the heat increment per calorie of metabolizable energy is usually greater in ruminants than in pigs and fowls, and it has been suggested by, among others, McClymont (1952), mainly on the basis of experiments with dogs (Lusk, 1921), that this is due to the heat increment of acetic acid produced in the rumen. This is an example of the elementary application of the biochemistry of digestion to the theory of net energy, and the procedure should be easy to carry out, but it must be realized that a more advanced attack might greatly increase the labour of experiments. Failing this approach there remains the accumulation of empirical values coupled with a rather more detailed chemical examination of the feeding-stuffs. With this plan of experiment one must hope that when an anomalous value for a feeding-stuff occurs, it will be additive or, failing this, that the explanation will be simple, such as failure to neutralize mineral acids in silage. There is room for compromise between the two extremes, so that the main issue is one of emphasis. It is to decide how much effort should be devoted to the biochemical elucidation of the theory of net energy, and how much to the empirical accumulation of net-energy values.

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Assessment of the Energy Value of Human Foods

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The energy value of food is measured in calories, which are physical units of heat. The number of calories a food will provide is usually calculated from the amounts of protein, fat, and carbohydrate in it, and these are estimated by chemical methods. Physiological corrections are then applied to allow for losses in the urine and the faeces. The whole subject is very complicated and the attempts which people have made to assess the energy value of human food can only be described as a comedy of errors. All the methods of assessment in use to-day are based upon work that was carried out over 50 years ago, and it is my object in this paper to go back to the great masters, Rubner and Atwater, to describe what they did and taught, to see how far their disciples have followed in their footsteps, and to discuss their teachings in the light of present knowledge.

I do not propose to deal with the question of losses in preparation or cooking of food, the problem of sampling, or the accuracy of methods of chemical analysis. Any one of these is a subject for a symposium in itself. I shall assume that the food has been sampled, prepared, and analysed in the best possible way and I