

The Development of Feeding Standards for Livestock

By CYRIL TYLER

WHEN writing of the historical development of a scientific concept, it is essential to give at least a general picture of the scientific ideas involved. A brief account of these ideas will, therefore, be given first.

If feeding stuffs are to be used to their full advantage, then it is essential for us to know something of their relative merits and of their effects upon the animal. Further, if they are to be quantitatively compared with each other, their value must be first expressed in terms of some unit, and their quantitative effect on the animal must also be measurable in these same units. Thus three feeding stuffs may contain x , y , and z units of nutrient material per hundred pounds respectively, whilst a cow may require m units of nutrient material to keep it alive and p units of material per gallon of milk. From this knowledge of the three feeding stuffs and the requirements of the cow, we should be able to decide theoretically on a suitable mixture of these feeding stuffs for the cow. Clearly this idea can be extended to all feeding stuffs and to all classes of product, such as eggs and meat. The historical development of feeding standards has therefore gone hand in hand with the nutritional evaluation of feeding stuffs, and both have progressed in the light of an ever growing knowledge of physiology and biochemistry.

At first, feeding stuffs *per se* were studied, and men learnt to know something of the worth of hay, turnips, oil cake, straw, and so on; but all the knowledge was empirical. Later it was recognized that each feeding stuff could be analyzed chemically and that the same chief groups of related compounds, namely fats, proteins, and carbohydrates, occurred in nearly all feeding stuffs. Thus the proportion of fats, proteins, and carbohydrates in the common feeding stuffs was established and feeds were compared and requirements stated on this basis. However, such an analysis did not take account of digestibility: this was, therefore, the next step.

Studies of digestibility soon made it obvious that the total quantities of fats, proteins, and carbohydrates in a feed were not a true measure of its worth to the animal, and so the emphasis passed to digestible fats, digestible proteins, and digestible carbohydrates. In other words, it was recognized that part of the feed is lost as faeces and is of no use to the animal.

The final stage was the recognition that even when a constituent of the

feed has actually been digested and absorbed into the body of the animal there may still be losses which vary under different conditions. Thus there are losses in the urine and breath and losses as heat from the lungs and skin. The digestible constituents cannot therefore be the final measure of worth, for this must be measured by what is left to the animal when all losses have been allowed for. It is this ultimate portion which enables the animal to maintain itself and to yield a product.

The measurement of productivity is relatively simple, in the sense that the live weight gain of a meat-producing animal or the gallons of milk from a dairy cow can be measured. The assessment of the needs for maintenance are less easy, but not impossible. If an animal yielding no product is made to fast, it will utilize its own body tissue in order to obtain the energy necessary for its life processes, and, very simply, it can be said that the energy so utilized must be exactly balanced by a supply of feed energy if the animal is just to maintain itself. Thus, by measuring the fasting metabolism of the animal, a value for its maintenance requirement is obtained.

In early literature there is not much evidence that the ancients had grasped any of these principles, although a few quotations and comments will indicate that they had an occasional glimpse of them.

As early as 2500 B.C. the Egyptians force-fed their fattening stock, as various pictures show, and this suggests that they realized that extra food gave fatter animals. Furthermore, the Hittite chariot-master Kikkuli wrote a treatise in 1350 B.C. which specifically dealt with the careful feeding of chariot horses. In his *Works and Days* Hesiod suggests that in winter, when the nights are long, oxen may be given half rations; and it is interesting to ponder whether this is the first glimmering of the concept that food requirements are related to activity and hence the shorter working hours of winter call for less food. Hippocrates expresses a similar idea but much more clearly when he says that "it is the nature of exercise to use up material, but of food and drink to make good deficiencies. . ." He also recognized that sometimes nourishment goes into being, but sometimes into both being and growth, which reminds us of maintenance and production. Meanwhile Aristotle took us some way in the study of body conformation and carcass quality, for he recognized that most of the fat in the animal body is laid down after the body has developed its bones and flesh.

Lucretius, writing in the first century B.C., also had something to say on the question of maturity and hinted at the balance of matter. In his *Nature of the Universe* he remarks:

"The things you see growing merrily in stature and climbing step by step the stairs of maturity—these are gaining more atoms than they lose . . . until

they have touched the topmost peak of growth. Thereafter the strength and vigour of maturity is gradually broken and age slides down the path of decay."

Finally, Columella, in the first century A.D., considered the question of quantities of food for cattle. He states that when oxen are tilling the ground they should receive 40 lb. of hay compared with 30 lb. when not doing so. Thus the conception of livestock feeding was advancing very slowly, but it was not becoming truly scientific, and it did not begin to do so until the beginning of the nineteenth century.

It has been suggested that about the middle of the eighteenth century the availability of a greater variety of feeding stuffs and the beginnings of a new forward surge in chemistry may have created the conditions for this development. Some authorities have also pointed out that stall feeding posed new problems in the utilization of feeds. Whatever the cause, it was Thaer in 1809, in his book *Grundsätze der rationellen Landwirtschaft*, who first put on record a table showing the relative values of different feeds. Thaer was a medical doctor who turned his attention to agriculture and finally became director of an agricultural institute at Möglin near Berlin, whilst his friend and helper, Einhof, was a chemist. Einhof began to study the nutritive materials in different feeds by treating them successively with water, dilute acid, dilute alkali, and alcohol. The residue was considered to be of no nutritional value, and therefore, by difference, the part which dissolved was the nutritive part. Thaer based his work upon Einhof's data and finally produced a set of relative values. For such a table to be of any use it is usual to adopt one particular feed as standard. Thaer, in selecting hay, states: "As hay is more known and more used than any of the other kinds of fodder, I shall make that article the standard by which all the others may be compared."

He gave the value of 100 to hay and expressed all other feeds in terms of his famous hay equivalents. Thus the hay equivalent of potatoes was given by Thaer as 200, indicating that 200 lb. of potatoes were equivalent to 100 lb. of hay. These values did not achieve much success, one of the chief reasons being that Thaer had selected for his standard one of the most variable feeds on the farm. Another reason was that the hay equivalent of a feed would vary according to the quantity and quality of the rest of the ration. Later writings made these difficulties quite clear, for soon most feeds had nearly as many hay equivalents as there were writers on the subject. However, before leaving Thaer it is important to note that it is generally implied that Thaer was seeking to establish the relative merits of various feeds as feeds, but a reading of Thaer's original book suggests that he was far more interested in the pro-

duction of manure and used Einhof's nutritive values because he believed that since fattening bullocks retained so little of their food, the more nutritious foods would produce a greater quantity of manure. Thus, he says: "There is no doubt that an accurate knowledge of the nutritive power of different vegetables would enable us to form some tolerably close calculations respecting the quantity of manure which they would produce." Furthermore, at no time did Thaer suggest a feeding standard for stock. It is of interest to note that in a tract published in London in 1812 a statement was made of the relative values of foods for human beings, giving a number to each food, rather on the lines of Thaer's system.

Meanwhile Magendie, in 1816, recognized the importance of the division into nitrogenous and non-nitrogenous food constituents, and Prout in 1834 divided the constituents of foods into three major groups: saccharine (carbohydrates), oleaginous (fats), and albuminous (proteins).

Boussingault, a French scientist, expressed the opinion in 1837 that nitrogenous compounds in the feed were the most important. In his *Économie Rurale*, published in 1843, he said: "The nutritious principles of plants and their products reside in their azotized (nitrogenous) principles, and consequently their nutritious powers are in proportion to the quantity of azote (nitrogen) they contain."

This idea was based on a number of points. Clover, lucerne, and sainfoin contained larger quantities of nitrogenous material than the more traditional fodders and also gave better results. Milk was rich in these nitrogenous compounds and was vital to the young animal building up its tissues. Horses broke down muscle when they performed work and hence required nitrogenous materials to repair their tissues. Finally, the Bramah oil press was invented at the end of the eighteenth century and linseed cake and decorticated cotton cake were increasing rapidly in popularity. These successful feeding stuffs were rich in nitrogenous material. Boussingault, therefore, put forward a table comparing foods on the basis of their nitrogen content, but admitted the need of other substances and went on to say that information on undigested materials would help even further. But, like Thaer, he proposed no feeding standard.

The great Liebig made many magnificent contributions to both pure and applied chemistry, but from our point of view his statement of the function of protein and other constituents was of great significance. He believed that fats and carbohydrates supported respiration and that proteins were capable of conversion into blood and thence into other tissues. In his book *Animal Chemistry*, which was published in 1842 and was a report to the British Association, he said: "... substances of which the food . . is composed may

be divided into two classes, into nitrogenized and non-nitrogenized. . . The former may be called the plastic elements of nutrition; the latter, elements of respiration."

We now know that these ideas were not entirely true, but even so the step forward was important. Liebig also expressed, as early as 1842, the opinion that the fat of the herbivorous animal must be derived to a great extent from the carbohydrate of the diet. Strong support for this came ten years later when Lawes and Gilbert of Rothamsted published the results of their pig experiments.

So far, workers had only dealt with the relative values of feeds, and no mention had been made of the needs of stock in terms of anything other than the feeds themselves. However, in 1853 Playfair, who had come under the influence of Liebig, gave a lecture at the Royal Institution in which he estimated diets for human beings in terms of nitrogenous and non-nitrogenous ingredients. He also discussed the requirements of some farm animals in terms of flesh-forming (protein) material. On the basis of chemical analyses Grouven, in 1858, in his book *Vorträge über Agrikulturchemie*, set forth the first feeding standards. He expressed the requirements for stock in terms of total fats, proteins, and carbohydrates. Thus a 1,000 lb. milch cow requires, per day, 2.84 lb. of crude protein, 0.84 lb. of crude fat, and 14.34 lb. of carbohydrate. However, this concept did not last long, for it was quickly becoming apparent that although digestion prepared the food for absorption, there were considerable losses of material in the faeces.

Nevertheless it would be wrong to dismiss the work of Grouven so briefly, for he was one of the great pioneers of animal nutrition. In the first place he recognized that live weight gains were not necessarily a true measure of the value of a food and that detailed studies of the gains and losses of protein and fat in an animal were required. Secondly, he recognized the great importance of chemical studies; and thirdly, he saw the importance of studies on fasting animals. A number of workers had studied the fasting animal before Grouven: for example, Magendie in 1852 had studied the fasting horse; but Grouven's intensive study of the fasting metabolism of cattle in 1864 was a model of its kind and preceded all similar work on cattle by over fifty years.

The concept of digestibility had begun its modern development when von Helmont (1577-1644) pointed out that gastric changes were something more than just grinding and mixing processes. Some of the major discoveries after this were as follows: Réaumur (1683-1757) performed experiments on birds and showed that gastric juice attacked some constituents of the diet but not others. By 1822 W. Beaumont (1785-1853) had shown that gastric juice contained some active substance which was responsible for much of the effect of

the juice; and two years later W. Prout (1785-1850) firmly established the presence of hydrochloric acid in gastric juice. However, there are other important aspects of digestion besides gastric juice. By 1856 Claude Bernard (1813-78) had studied the function of pancreatic juice as a substance which broke down starch, fat, and protein, and in 1854 Haubner showed that cellulose could be digested.

So the body of knowledge about the digestive processes grew, aided by information from a variety of sources. The next step was to obtain some quantitative facts about it in relation to domestic animals. The first true digestibility trials on farm stock were carried out at the Weende Experiment Station near Göttingen by Henneberg and Stohmann. They began their experiments in 1858, and in 1860 published *Beiträge zur Begründung einer rationellen Fütterung der Wiederkäuer*. In it they condemned Thaer's hay equivalents and gave results of their experiments. They also estimated, on the basis of experiments in which oxen just maintained their weight, the quantities of digestible nutrients which enabled the oxen to do this. These values were 0.57 lb. of digestible protein, 0.28 lb. of digestible fat, and 7.14 lb. of digestible carbohydrate per 1,000 lb. live weight per day. A second volume of their book came in 1863, and further experiments were performed by other workers under the general direction of Henneberg. Since then many thousands of digestibility trials have been carried out.

Meanwhile Emil von Wolff, the director of the Royal Agricultural College at Hohenheim, had been trying to modernize the Thaer system, by taking into account the fibre and the nitrogenous substances as well as the soluble material, but the publications of Henneberg and Stohmann convinced him that this concept was now outdated. In 1874 Wolff published his book *Die rationelle Fütterung der landwirtschaftlichen Nutztiere*, and in it he expressed the requirements of stock in terms of digestible fat, digestible protein, and digestible carbohydrate. To do this he examined all the existing records of feeding trials and converted the requirements into terms of digestible constituents. His standard for a 1,000 lb. milch cow was 2.5 lb. of digestible protein, 0.4 lb. of digestible fat, and 12.5 lb. of digestible carbohydrate per day. Wolff's standards were, from then on, published annually in Menzel and von Lengerke's Agricultural Calendar, and continued to be published with modifications until 1896. It should be noted that Wolff's chief standard was for a cow giving 20 lb. of milk but he made no suggested modification for other yields.

About 1880 Armsby in America had embarked on a translation of Wolff's book, but ended up by writing a first-class account of all the main researches on this subject up to that time. This is his well-known *Manual of Cattle*

Feeding. Then in 1895 Cousins published an English translation of Wolff's book under the title of *Farm Foods*.

In all this work, despite Grouven's study of the fasting animal, there was no recognition of the fact that food has two functions to fulfil, namely, to keep going the vital processes of the animal, i.e. maintenance, and to provide for production. Professor Julius Kuhn was director of the Agricultural Institute at Halle, and he criticized all the earlier work on this basis. In his book *Die zweckmässigste Ernährung des Rindviehs*, published in 1887, he put forward two ideas. First, that foods provide for maintenance and production, and secondly that the cow has a limited capacity to deal with the dry matter in a ration. His second proposition stressed, for the first time, the importance of bulk. His first point is usually accepted as the first statement made on the idea of maintenance and production rations. It is, therefore, of considerable interest to note that not later than 1843, i.e. nearly fifty years earlier, Veit had, in his *Lehrbuch der Landwirtschaft zum Gebrauch in Landwirtschaft- und Gewerbs-Schulen*, stated quite clearly that fodder could be divided into conservation and melioration fodder, and that the one served for maintenance and the other for production. The actual statement reads as follows: ". . . conservation fodder is the quantity of fodder necessary to keep the animal alive in his present state, and melioration fodder is the quantity necessary to be employed in improving his condition."

In 1897 Lehmann, of the Berlin Agricultural High School, modified Wolff's standards in the light of Kuhn's criticisms, and in the form of Wolff-Lehmann Feeding Standards, they continued to be published in the Agricultural Calendar, and were used throughout the world. The step had now been taken to recognize that the quantity of a product clearly modified the needs of an animal, but in 1903 Haecker, at Minnesota, advanced this concept even further by pointing out that in the case of milk its percentage of fat, that is, its quality, will also influence the needs of the animal. On this basis he put forward new standards, but, of course, they were still based on digestible nutrients.

Despite these advances the nutritionists and the agricultural chemists were not satisfied. In 1842 Mayer had put forward his law of the conservation of energy. Helmholtz generalized it five years later, and this had repercussions on all branches of science, not excluding nutrition. As early as the sixteenth century it was recognized that losses, other than faeces and urine, occurred from the body. This loss was referred to as insensible perspiration. Sanctorius, a professor in the Medical School at Padua, carried out many experiments on himself to try and measure this, and described them in his book *De medicina statica aphorismi*, published in 1614. In a sense these were the

first rudimentary balance experiments. But it was Boussingault who performed the first true balance experiments in 1839, when he investigated the intake and outgo of carbon, hydrogen, oxygen, nitrogen, and ash in a dairy cow. He realized, however, that he had not taken the gaseous excreta into account. By 1849 Regnault (1810-78) with Reiset was using a respiration chamber to measure gaseous exchanges in the animal, and in 1852 Bidder and Schmidt published their classical *Die Verdauungssäfte und der Stoffwechsel*, in which the idea of a complete balance-sheet of the material incomings and outgoings of an animal was set down. From 1857 onwards Voit, who had been a pupil of Liebig, and who is regarded as the founder of modern nutrition, developed these ideas still further. He and Pettenkofer built a much better respiration chamber in 1866, and, with others, they considerably extended the concept of metabolism. Furthermore, in 1887 Voit suggested the amounts of fat, protein, and carbohydrate required daily by human beings. Lavoisier and Seguin showed as early as 1789 that respiration and combustion are similar processes, i.e. both consist of the burning of organic compounds in oxygen to give energy, including heat, but it was not until 1893 that Rubner began to use his animal calorimeter in which it was possible to measure heat output as well as material excreta. This was a great step forward, and, in addition, it enabled him to relate the maintenance requirement of an animal to its surface area. His results were published in 1902 in his *Die Gesetze des Energieverbrauchs bei der Ernährung*. And at about the same time Atwater and Armsby in the United States began to use the animal calorimeter for their work on human beings and cattle respectively.

The great pioneers Henneberg and Stohmann lost no time in carrying out respiration experiments on farm animals, but unfortunately Henneberg's death put an end to them. However, Gustav Kuhn began similar experiments at Möckern, and in 1893 he was succeeded by Oskar Kellner. From 1893 onwards Kellner continued the work, and in 1905 he published his book *Die Ernährung der landwirtschaftlichen Nutztiere*. This took the idea of feeding to its logical conclusion, for Kellner carried out carefully controlled balance experiments in which he determined all forms of material loss from the animal: faeces, urine, and breath. In this way what finally remained in the animal represented that part of the ration which was truly of value to it for productive purposes. The value of 100 lb. of any feeding stuff was then equated to so many pounds of starch, and thus arose the famous "starch equivalent." This represented the productive energy of the ration whilst in addition Kellner gave a protein value in terms of digestible true protein. In actual fact Kellner's work was more fundamental than this,

because he established the producing value of pure digestible fat, protein, and carbohydrate, irrespective of the feeds in which they occurred. From these fixed values he was able to calculate the theoretical starch equivalent of any feeding stuff, and then by applying a correction for fibre, he obtained an actual value. It is, perhaps, important to point out that Kellner used fattening bullocks in his experiments, but that in 1911 he modified his ideas to cover milking cows as well. Thus starch equivalents were calculated for all feeding stuffs and the requirements of all classes of stock were expressed in the same terms. It became a popular system and forms the basis of present-day methods of scientific rationing in this country.

A little later than Kellner, Armsby, in America, attacked the problem from a somewhat different angle, using the animal calorimeter, and calculated what he called "Net Energy Values." However, fundamentally, it was the same basic idea as Kellner's.

Since this time a number of refinements and modifications have been suggested, but they do not carry us beyond the basic concept of Kellner and Armsby. This concept is the most logical idea, but its very accuracy and its variations with changing conditions, though predictable, make it in many ways unsuitable for farmyard approximations. And, in fact, in America nutritionists have turned back to a modified concept of the digestible nutrient idea of Wolff. However, this is not necessarily a retrograde step, because many thousands of digestibility trials have been performed against only a very few balance experiments, and the greater amount of information, plus an equal accuracy of determination, may well offset the lesser accuracy of the principle in a problem of this kind.

We cannot leave this historical outline without a brief mention of a system which developed away from the main line of events, namely the Scandinavian system. Fjord was the originator of this idea, and, according to Wilson, "... he was not an agriculturist. Nor was he a chemist. But he was a man of unusual ability and common sense." The work is supposed to have begun more or less by accident when Fjord was asked to settle a serious dispute. About 1880 the milk separator was being used on Danish farms, and it was being said that separated milk was much inferior to skim milk as a feed for pigs and calves. Fjord decided to carry out experiments to test the relative merits of the two milks. His method was recognized as sound, and, obviously, once started there was no end to this kind of problem, so the work of comparing feeding stuffs grew. In 1887 he published his results, based on many feeding trials, and from these results he worked out a new system of equivalents on similar lines to Thaer's. However, he was more fortunate than Thaer because he chose cereals instead of hay for his unit. This unit was

fixed at half a kilogram of a fifty-fifty mixture of barley and oats. All food values and all requirements of stock were expressed on the basis of this unit. Others continued the work, and in 1908 Hannson suggested one kilogram of barley as the new unit. This new unit was adopted throughout Scandinavia in 1915. The method has certainly proved successful in these countries, and it is usually maintained that this is owing to their smaller variety of feeding stuffs and their more uniform system of feeding.

Finally, comment may be made on the general concept of feeding standards. Clearly, for any system to work on the farm, it must involve no complicated mathematics. To express the value of a food in terms of one number renders calculations easy, to express it in terms of two numbers renders calculation more difficult, and progressively so with each additional number. Secondly, feeding standards do not take into account the mineral constituents of a ration, or the vitamins, or its palatability, for to do so would make their use exceedingly complex, but nevertheless these items are important to the animal. Furthermore, no matter how correct the values may be, they are always statistical averages. Oats have a starch equivalent of 60, but obviously not all samples of oats will have this value, which is only an average. Similarly, if the daily need of a 1,000-lb. cow for maintenance is 6 lb. of starch equivalent, this does not mean that every 1,000-lb. cow has this requirement. Therefore, however refined our scientific rationing may become, there will always be the need for an expert stockman to watch the individual needs of his animals, and this will continue until we finally rule out of our farm animals those biological variations which create individuality. Until then, the King of Persia, as quoted by Xenophon in the fourth century B.C., will be right, for he said that it is the eye of the master which makes the horse fat.

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Notes and Comments

THE BRITISH AGRICULTURAL HISTORY SOCIETY

The fourth Conference and Annual General Meeting of the Society was held at Florence Nightingale Hall, the University of Nottingham, on Thursday 12 and Friday 13 April 1956. It was attended by about thirty-five members. The Conference began on the Thursday evening with an illustrated talk by Mr John Higgs, Keeper of the Museum of English Rural Life, the University of Reading, on problems of identification encountered at the Museum. There were two papers on the Friday: the first, by Mr Malcolm Gray, Lecturer in Economics at the University College of North Wales, on the Consolidation of the Crofting system from 1750 to 1850; the second, by Dr W. G. Hoskins, Reader in Economic History at the University of Oxford, on Sheep-Farming in Saxon England. In the afternoon members were conducted round the open fields of Laxton by Dr J. D. Chambers and the Bailiff of the Manor.

The President, Sir James Scott Watson, took the Chair at the Annual General Meet-

ing which was held on the Friday morning. The retiring officers were re-elected, and Miss H. A. Beecham, Mr G. Ordish, and Dr Joan Thirsk were elected to the Executive Committee in place of Mr W. E. Minchinton, Mr F. G. Payne, and Mr R. Trow-Smith who had retired.

The Chairman of the Executive Committee, Mr Alexander Hay, was able to report that the Society had had a good year and that membership stood at four hundred and ten. The Treasurer, Professor Edgar Thomas, reported that the balance in the bank as at 31 January was £226 11s. 7d.

At a meeting of the Executive Committee it was decided to hold the usual one-day Conference with the Association of Agriculture in London on a Saturday early in December, and the Annual General Meeting in Bristol in April 1957.

CENTENARY OF THE CURTIS MUSEUM

In 1955 the Curtis Museum at Alton in Hampshire celebrated its centenary. The story of this active local museum has been set

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