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THE COMPARATIVE MERITS OF ANIMAL AND VEGETABLE FOODS IN NUTRITION

Chairman: PROFESSOR R. C. GARRY, *Institute of Physiology, University of Glasgow*

Chairman's Opening Remarks

By R. C. GARRY, *Institute of Physiology, University of Glasgow*

Controversy concerning the relative nutritive merits of protein from plant and animal sources is of long standing. Our conception of the total quantity of protein required has also swung wildly from one extreme to the other. This scientific problem, intrinsically difficult in itself, has been, and still is, emotionally bedevilled by prejudice and sentiment.

Recent advances in biochemistry have given us a better appreciation of the ultimate composition of proteins from different sources, and have helped to explain and foretell the 'biological values' of different proteins. Nevertheless, we must not forget that we do not eat proteins as such, we eat food containing protein. And evidence is accumulating that the value of the protein may depend to some extent on the vehicle in which it is presented. The time is propitious for stocktaking, for a review of the past, for a forecast of the future. This is the purpose of our conference to-day.

Biochemistry of Animal and Vegetable Proteins

By G. R. TRISTRAM, *University of St Andrews*

Text not received for publication.

The Relative Nutritional Values of Animal and Vegetable Proteins for Animals

By K. J. CARPENTER, *Rowett Research Institute, Bucksburn, Aberdeenshire*

The classical method for the nutritional evaluation of the protein complex in individual foods or feeding-stuffs is to feed them, at a level of 10% protein, as the sole protein source in the otherwise adequate diet of young, growing rats. The material is then rated either by its digestibility and biological value (the proportion of the absorbed nitrogen which escapes excretion in the urine) or by the protein-efficiency ratio (the gain in weight of the rat per g. protein eaten). From an examination of published data for thirty-eight materials Block & Mitchell (1946–7) found a very high degree of correlation ($r = +0.84$) between the protein-efficiency ratio and the net protein utilization (digestibility × biological value).

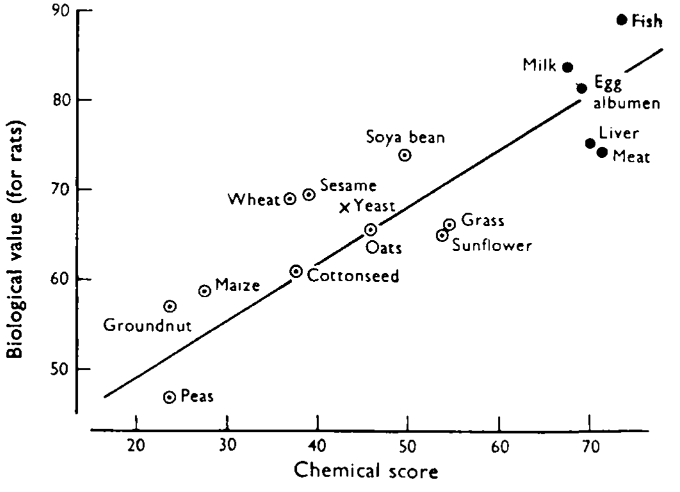

Fig. 1. Correlation diagram of the biological value and chemical score of sixteen animal (●) and vegetable (⊙) materials. (Data from Mitchell & Block, 1946; Bartlett, Henry, Kon, Osborne, Thompson & Tinsley, 1938; Harrison, Anderson & Pottinger, 1935.)

Figures of fair reliability are available for the essential amino-acid content of most common feeding-stuffs, and for these Block & Mitchell have calculated a chemical score in terms of whole-egg protein, which is almost wholly utilized by the young rat. This is obtained by calculating the content of each essential amino-acid in the protein ($N \times 6.25$) of a material as a percentage of the concentration of the same amino-acid in whole-egg protein. As the limiting amino-acid is held to determine the value of the whole protein, the lowest percentage obtained is used as the chemical score.

In Fig. 1 some of the available data (mostly from Mitchell & Block, 1946) for the chemical score and biological value of materials of interest in animal nutrition are set out in diagrammatic form. Again there is a high degree of correlation between the two methods of evaluation. The data show the general superiority of the animal materials over those of vegetable origin. Only soya-bean meal, toasted to destroy the trypsin inhibitor it contains, is within the range of the animal proteins.

These figures for biological values would be invalidated if it were shown that the animal materials alone carried with them vitamins which affected the utilization of protein, and in which the rat was deficient.

Vitamin B_{12}-deficient rats have an increased requirement for methionine (Schaefer, Salmon & Strength, 1949) and the work of Bosshardt, Ayres, Ydse & Barnes (1946) suggests that utilization of dietary protein will be impaired. This vitamin is found in animal materials, but is absent from unfermented vegetables, as also from the basal diet used in the trials referred to. Nevertheless, the rats will almost certainly have carried sufficient reserves of vitamin B_{12} from their suckling period to prevent a deficiency in the short experimental period (Zucker & Zucker, 1948). This is confirmed by the biological values for the vegetable, as compared with the animal, feeds being at least as great as would be expected from the relative chemical scores of the two classes.

These rat experiments represent necessarily a great simplification of the practical problem of making up balanced rations at low cost. There remain the possibilities of less exacting requirements in later life (when a much greater aggregate of feed is consumed), mutual supplementation between vegetable proteins, and species differences.

Cattle and sheep

The ruminants, with the exception of the period when they are suckling (Blaxter & Wood, 1950), have an alimentary microflora encouraged by the dynamics of the digestive system to attack the feed for a considerable time. The micro-organisms have wide powers of synthesis. When urea is given as the sole source of nitrogen, all ten of the essential amino-acids are found in the rumen in approximately the same quantities as after feeding a good-quality protein (Thomas, Loosli, Ferris, Williams & Maynard, 1949).

It is not surprising, therefore, that for ruminants the proteins in the common feeding-stuffs, whether animal or vegetable, are generally similar in biological value (McNaught & Smith, 1947). Moir & Stewart (1947) showed that legume seeds low in the sulphur amino-acids were of low value in promoting heavy wool growth, but a requirement by sheep for dietary cystine and methionine has not yet been proved.

The major feed of both cattle and sheep is fresh herbage, which should meet their maintenance requirements for protein, and even sustain a moderate level of production.

Pigs and poultry

Pigs and poultry, both monogastric species, cannot tolerate the high level of fibre in a ration composed mainly of grass, and in practice the cereal grains and offals form the main source of energy in their rations. For poultry of all ages and for pigs (except during fattening), a mixture of cereals is deficient in protein. The practical problem is therefore to assess the relative values of animal and vegetable proteins as supplements to cereals for these two species.

So far, individual amino-acid requirements have been worked out only for chicks. Calculations suggest that of all the essential amino-acids only lysine and the sulphur-containing amino-acids, cystine and methionine, will be limiting factors in practical rations, and their concentration in sixteen feeding-stuffs (De Man, 1949) is shown diagrammatically in Fig. 2.

One criticism of experiments with supplementary proteins is that the results may apply only for the particular basal mixture used. However, the similar composition of the main cereals suggests that supplementary values should not differ greatly with the cereal mixture. This was confirmed when maize and wheat were tested separately with a series of fish meals and meat meals (March, Stupich & Biely, 1949).

The approximate percentages of lysine and cystine+methionine required in the protein of a chick ration containing 20% protein have been determined (Almquist, 1947) and are shown in Fig. 2. By analysis, the cereals should be deficient in lysine and border-line for the sulphur amino-acids, and this was confirmed for a wheat-protein preparation (Jeppesen & Grau, 1948).

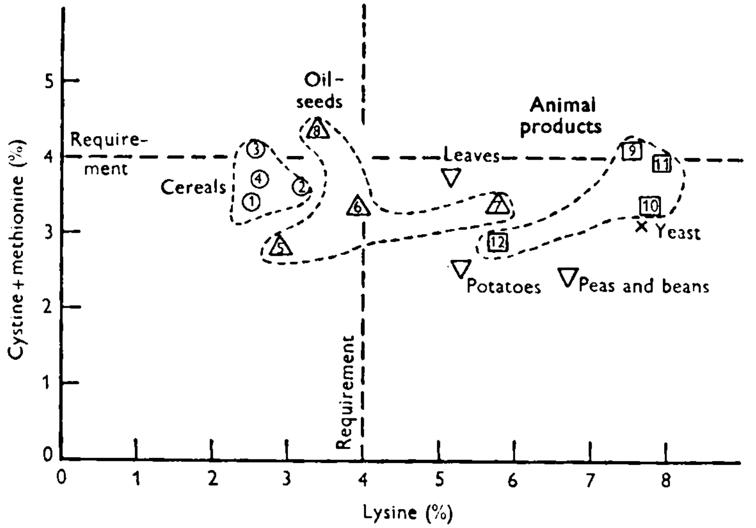

Fig. 2. Lysine and 'cystine+methionine' in the crude protein of sixteen feeding-stuffs, and the requirement of these amino-acids by the chick in an 'ideal' protein fed at 20% level. In each case the requirement is 0·8% of the total ration or, as shown here, 4·0% of the protein. (Data from Almquist 1947; De Man, 1949; and Grau & Kamei, 1950.) 1. Barley. 2. Oats. 3. Maize. 4. Wheat. 5. Groundnut. 6. Cottonseed. 7. Soya-bean. 8. Sunflower. 9. Fish meal. 10. Blood meal. 11. Skim milk. 12. Meat meal.

The common animal feeding-stuffs are generally higher in lysine than the vegetable feeds, and so appear better able to supplement the cereals. Soya-bean meal again appears to be outstanding among the vegetable proteins. Meat meal is inferior to the other animal feeds by analysis, and a large proportion of the lysine may also be unavailable to the chick (March, Biely & Young, 1950). The lysine of groundnut meal, though present at a low level, is mostly available (Carpenter & Ellinger, 1951).

There are some differences between the methionine content of feeds as estimated by chemical and microbiological methods (De Man, 1949), but it is clear that though some of both classes of supplements are deficient in the sulphur-containing amino-acids, no protein has a compensating excess.

Heiman, Carver & Cook (1939) have suggested a standard method of evaluating supplementary proteins for chicks, using a basal 8% protein ration of mixed cereals and vitamin concentrates. The supplements are added, for different groups, to give 3% additional protein. Their gross protein value (G.P.V.) is the extra growth obtained (in 2 weeks) divided by the supplementary protein eaten. The values are expressed as a percentage of that obtained for casein.

Table 1 shows the results obtained for a series of feeding-stuffs with the original method (Robertson, Carver & Cook, 1940), and with the crude-fibre level kept constant (Carpenter, Duckworth & Ellinger, 1951). The results for animal materials, and for extracted oilseeds are in good agreement with the expectations based on their amino-acid composition. The low value for cottonseed meal may be attributed to the presence of toxic material in the sample (Ingram, Cravens & Elvehjem, 1950).

Table 1. *Gross value* of protein supplements for chicks* (*casein* = 100)

(The figures are the mean values obtained with each feeding-stuff)

Supplement	U.S.† results	U.K.‡ results
Animal products:		
Casein	100	100
Herring meal	101	95
White fish meal	—	89
Dried skim milk	90	—
Meat meal	55	—
Oilseeds:		
Soya-bean meal	76	—
Groundnut meal	—	50
Cottonseed meal	25	—
Coconut meal	22	—
Herbage:		
Lucerne meal	37	27
Lucerne meal and 0·15 % cholesterol	—	70
Grass meal	—	55
Grass meal and 0·15 % cholesterol	—	58
Red clover meal	—	46

* For definition see p. 246.
† Robertson *et al.* (1940).
‡ Carpenter *et al.* (1951).

The first value obtained for lucerne meal was low, considering the promising analyses obtained for leafy materials. However, Peterson (1950) showed that lucerne contains a 'saponin-like' growth-depressant inactivated by the addition of cholesterol, and the G.P.V. for lucerne was greatly increased by adding 0·15% cholesterol to the ration. Ordinary grass meal appeared not to contain this growth-depressant to any significant extent. The values for the leafy materials tested are still lower than for soya-bean meal, though amino-acid analyses suggest that they should be of approximately equal value. The analyses may be wrong, or alternatively the leaf proteins may be less digestible. Of the sixteen materials for which data from rat experiments are given in Fig. 1 above, all had a digestibility greater than 90%, with the exception of grass meal for which the figure was 67%.

If it is accepted that vegetable protein supplements are generally inferior to the animal ones, the problem is to determine how far the inferiority can be made up by giving the supplementary protein at higher levels.

Fig. 3, based on the results of three comparable chick trials lasting 4–6 weeks, shows the findings with herring meal and groundnut meal as supplementary proteins. The growth rates converge as the level of supplementation increases. The proportion, however, in which the two supplements have to be fed in order to produce any given growth rate is constant (in this instance 2 : 1). This would be expected if the requirement for the individual amino-acids remained constant within the range of protein levels used.

It has been shown by Grau & Kamei (1950) that the individual requirements for lysine and methionine increase when the protein level of the chick ration is raised to 30 or 40%. With a sufficiently unbalanced protein, additional supplementation should then make things worse rather than better. With groundnut meal, one of the poorer protein sources in common use, this does not occur, and the leeway can be made up by increasing the level (Fig. 3).

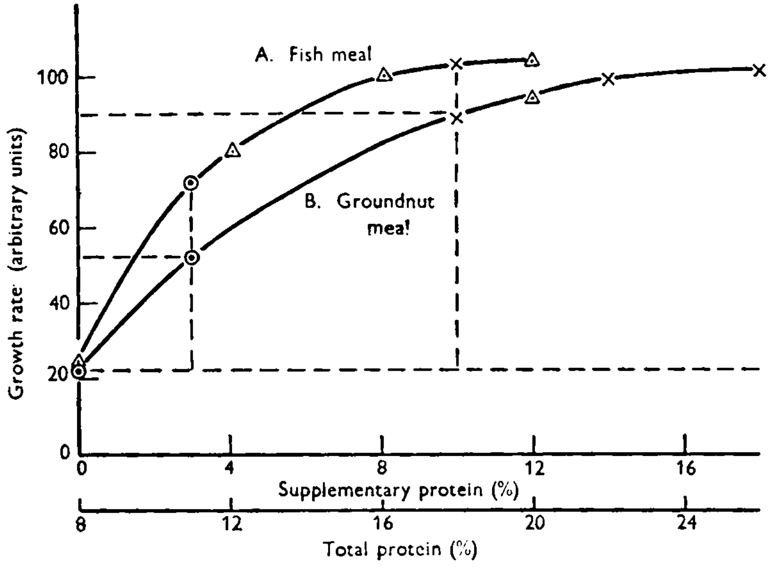

Fig. 3. Growth of chicks in the first 4–6 weeks of life according to protein level, and nature of protein supplement. Combined data from three experiments (Carpenter *et al.* 1951). △ = Exp. 1; ⊙ = Exp. 2; × = Exp. 3.

In practice, high initial growth rates are not an end in themselves, and we have found that a groundnut ration of normal protein level will finally produce a healthy bird at point of lay with the same feed-conversion efficiency as will a fish-meal ration giving a higher growth rate for the first few weeks (cf. Halnan, 1948).

In laying trials, with rations containing a total of 14–15% protein, fish meal has been replaced, without any significant differences resulting, by either soya-bean meal (Forrest, Biely & March, 1950), sesame meal (Hale & Bolton, 1948) or groundnut meal with palm-kernel meal (Temperton & Dudley, 1939–40). This contrast with the chick results could be due to a greater ability of the older animal to synthesize some of the essential amino-acids. A simpler explanation may be that the fish meal in the rations is in excess and could be reduced without effect, but that the level of the vegetable proteins could not be reduced.

General conclusions

Animal protein feeding-stuffs such as fish meals and dried skim milk are rich sources of vitamins, important for non-ruminant livestock. The recent introduction of condensed fish solubles, 'animal protein factor' concentrates from the antibiotics industry and synthetic riboflavin as alternative sources of these vitamins will provide a greater field for the use of otherwise suitable vegetable proteins which are not also potent sources of these factors. Research has shown that they are generally inferior to animal proteins, but that this may be made up for by feeding them at higher levels. Whether such a change is economically worthwhile will depend upon the cost of any extra vitamin supplements needed, as well as on the relative cost of the protein supplements themselves.

The use of vegetable proteins may be particularly important in the colonial development areas where fish meal and milk products are not normally available for pig and poultry feeding. Unfortunately, ordinary grass and leaf meals are high in fibre, and cottonseed meal contains a growth depressant. These limit their usefulness at present, but new processing methods may be worked out to overcome these difficulties.

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