A METHOD OF EXPRESSING NUMERICALLY THE GROWTH-PROMOTING VALUE OF PROTEINS.*

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A young animal continuously increases its food intake during growth, hence two which grow at different rates eat unlike quantities of food. We have already pointed out that comparisons of the value of different proteins for growth can be made when the animals eat the same amount of food in the same number of days and gain the same amount of weight, the protein factor being the only variable. As it is exceedingly difficult to conduct experiments which fulfil these requirements we have sought to develop a method whereby the relative values of proteins for growth can be expressed numerically.

Since food intake is quite closely regulated by the calorific requirements of the animal approximately as much food is eaten under otherwise similar conditions whether this contains a high or low percentage of protein. If a single series of experiments is made with diets containing a given percentage of protein it is obviously impossible to demonstrate the maximum power of any protein to promote growth. When the proportion of protein in the food is so restricted that the protein factor alone determines the rate of growth, it should be possible to find the concentration which promotes the greatest gain of body weight relative to the protein ingested by supplying foods containing different percentages of protein. However, this is possible only within

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1 Cf. Osborne, T. B., and Mendel, L. B., J. Biol. Chem., 1916, xxvi, 1.
limits, for differences in physical activities and the inherent capacity of the animal to grow may affect the amount of growth made within a fixed time. Consequently we cannot expect that,

on a given diet, each animal will make quite the same gain of weight during equal intervals of time. How great these individual variations may be is illustrated by the data given in Tables I and II. From these we see that while the absolute

| Source of protein. | in food | Rat. | Initial body weight | Gain in food | Total intake | Intake per gm. of gain | Gain per gm. of food |
|--------------------|--------|------|---------------------|--------------|--------------|-----------------------|---------------------|
| Lactalbumin.       |        |      |                     |              |              |                       |                     |
| 16.2%              | 2920   | 62   | 64                  | 208          | 33.2         | 3.3                   | 0.52                | 0.31                | 1.93                |
|                    | 2924   | 61   | 74                  | 192          | 30.7         | 2.6                   | 0.42                | 0.39                | 2.41                |
|                    | 1810   | 73   | 60                  | 202          | 32.3         | 3.4                   | 0.54                | 0.30                | 1.86                |
|                    | 1812   | 67   | 45                  | 169          | 27.0         | 3.8                   | 0.60                | 0.27                | 1.67                |
| Average            |        |      |                     |              |              |                       |                     |                     |                     |
|                    | 61     | 198  | 30.8                | 3.3          | 0.52         | 0.32                  | 1.97                |
| Lactalbumin.       |        |      |                     |              |              |                       |                     |
| 10.3%              | 2474   | 71   | 60                  | 213          | 21.9         | 3.6                   | 0.37                | 0.28                | 2.74                |
|                    | 2831   | 63   | 47                  | 180          | 19.5         | 4.0                   | 0.42                | 0.25                | 2.41                |
| Average            |        |      |                     |              |              |                       |                     |                     |                     |
|                    | 54     | 201  | 20.7                | 3.8          | 0.40         | 0.27                  | 2.58                |
| Lactalbumin.       |        |      |                     |              |              |                       |                     |
| 7.9%               | 2625   | 64   | 62                  | 250          | 19.5         | 4.0                   | 0.31                | 0.25                | 2.58                |
|                    | 2631   | 70   | 56                  | 254          | 19.8         | 4.5                   | 0.35                | 0.22                | 2.83                |
| Average            |        |      |                     |              |              |                       |                     |                     |                     |
|                    | 59     | 252  | 19.7                | 4.3          | 0.33         | 0.24                  | 3.01                |
| Lactalbumin.       |        |      |                     |              |              |                       |                     |
| 6.2%               | 2596   | 66   | 31                  | 194          | 12.0         | 6.3                   | 0.39                | 0.16                | 2.58                |
|                    | 2606   | 67   | 39                  | 233          | 14.5         | 6.0                   | 0.37                | 0.17                | 2.69                |
| Average            |        |      |                     |              |              |                       |                     |                     |                     |
|                    | 35     | 214  | 13.3                | 6.2          | 0.38         | 0.17                  | 2.64                |
| Lactalbumin.       |        |      |                     |              |              |                       |                     |
| 4.9%               | 2044   | 63   | 18                  | 154          | 7.5          | 8.6                   | 0.42                | 0.12                | 2.40                |
|                    | 2049   | 63   | 19                  | 168          | 8.2          | 8.9                   | 0.43                | 0.11                | 2.32                |
| Average            |        |      |                     |              |              |                       |                     |                     |                     |
|                    | 19     | 161  | 7.9                 | 8.8          | 0.43         | 0.12                  | 2.36                |
| Lactalbumin.       |        |      |                     |              |              |                       |                     |
| 3.3%               | 2201   | 68   | 7                   | 131          | 4.3          | 18.7                  | 0.62                | 0.05                | 1.63                |
|                    | 2203   | 67   | 7                   | 172          | 5.7          | 24.6                  | 0.82                | 0.04                | 1.23                |
| Average            |        |      |                     |              |              |                       |                     |                     |                     |
|                    | 7      | 152  | 5.0                 | 21.7         | 0.72         | 0.05                  | 1.43                |
gains of body weight may differ by even 75 per cent, the differences between the gains in body weight per gm. of protein eaten are very much less, though by no means inconsiderable. It is consequently necessary to employ a larger number of animals

Table I shows that when the food contained 7.9 per cent of lactalbumin the maximum gain of body weight per gm. of protein eaten was 3.0 gm., which probably represents approximately the

| Source of protein | Food Protein | Initial body weight | Gain in weight |
|-------------------|--------------|---------------------|----------------|
| Casein            | 17.4         | 1592.9              | 17.4           |
|                   |              | 1599.9              | 16.2           |
|                   |              | 1617.7              | 14.9           |
|                   |              | 1618.9              | 14.7           |
|                   |              | 1634.9              | 14.4           |
|                   |              | 1652.9              | 13.7           |
|                   |              | 1655.9              | 13.5           |
|                   |              | 1657.9              | 13.3           |
|                   |              | 1689.9              | 12.8           |

Average 55.5 187 32.5 3.4 0.59 0.30 1.74

| Casein            | 14.7         | 2405.9              | 16.9           |
|                   |              | 2619.9              | 16.5           |
|                   |              | 2620.9              | 16.3           |

Average 67 229 33.7 3.5 0.52 0.29 1.98

| Casein            | 12.0         | 2117.9              | 17.1           |
|                   |              | 2623.9              | 16.9           |
|                   |              | 2630.9              | 16.7           |

Average 56 203 24.4 3.7 0.45 0.27 2.25

| Casein            | 9.3          | 2051.9              | 19.1           |
|                   |              | 2595.9              | 18.1           |
|                   |              | 2903.9              | 17.6           |

Average 25 184 17.1 7.6 0.70 0.14 1.45
maximum growth-promoting capacity of lactalbumin when fed to albino rats under the conditions of these experiments.

Table II gives similar data obtained with casein as the sole protein of the diet. Here the greatest gain per gm. of protein eaten was 2.25 gm., the food containing 12 per cent of casein. To make this maximum gain the rats ate on the average 24.4 gm. of casein and 203 gm. of food and gained 56 gm. When the food contained 7.9 per cent of lactalbumin the rats ate on the average 19.7 gm. of lactalbumin and 252 gm. of food and gained 59 gm. Thus to make the same gain in the same time under the conditions of maximum efficiency 24 per cent more protein and 20 per cent more food were needed when the protein was casein than when it was lactalbumin.

When an animal is restricted to such a quantity of protein that a maximum gain of body weight is made per unit of protein eaten, it grows at less than the normal rate. A longer time therefore is required to make a given gain of weight, and consequently more food is needed for maintenance than if growth had not thus been delayed. In these experiments nearly the same amount of food was eaten whether this contained 6.2 or 16.2 per cent of lactalbumin (see Table I), but the gain in weight was almost twice as great on the high as on the low protein food; namely, 61 and 35 gm. respectively, or 0.32 and 0.17 gm. of gain per gm. of food eaten. Although growth on the 6.2 per cent ration was made with the least expenditure of protein, the consumption of food was almost twice as great per gm. of gain as that on the 16.2 per cent diet. Consequently, although an economy in the consumption of protein may be effected by reducing its concentration in the diet, this is necessarily accompanied by a larger consumption of food.

The data given in Tables I and II may be compared with those previously obtained in attempting to establish by other methods the relative value for growth of lactalbumin and casein. Series A of the earlier experiments differed from those described in the present paper in that the food intake was restricted by supplying the diet in weighed quantities, estimated to be about 10 per cent less than was needed for full normal growth, and also in being continued for 11 weeks. From the data given in Table II of the earlier paper we have calculated the gains in body weight.
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per gm. of protein eaten for the entire 11 weeks, and also, for comparison with the experiments just described, for periods of 4 weeks following the time at which these rats had reached a body weight of about 70 gm. In recalculating these results we have estimated the protein from the nitrogen content of the diet whereby the nitrogen of the “protein-free milk” was included, as was done for the experiments described in this paper.

| Lactalbumin | 11 wks. | 4 wks. |
|-------------|---------|--------|
|             | per cent |       |       |
|             | Food.    | Protein. | Food. | Protein. |
| 16.0        | 0.279    | 1.74    | 0.325 | 2.03    |
| 11.1        | 0.228    | 2.06    | 0.240 | 2.16    |
| 9.2         | 0.176    | 1.91    | 0.200 | 2.17    |

| Casein      | 11 wks. | 4 wks. |
|-------------|---------|--------|
|             | per cent |       |       |
|             | Food.    | Protein. | Food. | Protein. |
| 17.4        | 0.240    | 1.38    | 0.273 | 1.57    |
| 12.0        | 0.194    | 1.62    | 0.193 | 1.61    |
| 9.2         | 0.162    | 1.76    | 0.164 | 1.77    |

The gains of weight per gm. of protein eaten during the 4 week periods were slightly higher than during the 11 week periods, presumably because the former coincide with the time of most rapid growth. The maximum gains were decidedly less in these 4 week periods than those obtained in our new experiments, probably because in the earlier trials growth also was restricted by the amount of food supplied, and not solely by the protein eaten. When growth is limited by food intake protein can be used as a source of energy and consequently a smaller part may be available for growth than when sufficient energy is supplied in other forms and growth is determined solely by protein.

In our former paper we called attention to criticisms, based on other grounds, which might be made to Series A of the earlier experiments, which was designed to show the relative value of proteins for growth. The comparison just made gives additional reasons for rejecting such methods of experimentation.

In Chart II of our earlier paper we showed that rats made equal gains of weight in equal periods of time and ate practically
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the same amount of food when diets of essentially the same composition were fed, but containing 8 per cent of lactalbumin, 12 per cent of casein, or 15 per cent of edestin. While the method employed for these experiments shows the relative growth-promoting power of these proteins it does not show their maximum efficiency. Thus the gain of weight per gm. of protein eaten during the 8 weeks of these experiments was for lactalbumin 2.34 gm., for casein 1.70, and for edestin 1.35 gm. These figures for lactalbumin and casein are decidedly lower than the maxima found by the method described in this paper, and the difference in the relative value of these proteins appears greater than it actually is.

For the investigator we believe that this new method, which shows with some degree of accuracy the maximum efficiency of individual proteins, or mixtures of them, for growth, will be of use. By its aid we can determine and express numerically the efficiency of combinations of proteins and compare this with that of either one alone. Differences in food intake and rate of growth are largely eliminated and experimental data can be used which cannot be compared in any other way.

This method has its limitations, for obviously when the protein of the diet is capable of promoting growth only at a very slow rate the amount of protein eaten per gm. of gain made will approach infinity as the gain approaches zero. The error thus introduced of course affects all comparisons made between figures obtained by the simple method of dividing the gain of weight by the gm. of protein eaten, but when the rate of growth on the two proteins thus compared is fairly rapid the magnitude of the error is small.

The practical feeder does not wish to know what quantity of a given protein is the smallest which he can use to secure a given amount of gain, if this quantity can only be used under unprofitable conditions. Rather does he want to know the least proportion which will give him the greatest gain in the shortest time, for although he may thereby waste some protein he may save food. The method described in our earlier paper (Series B) is better adapted to the use of the dietitian or the agriculturist in determining the relative value of proteins for growth than the method now described in this paper.
The effect of restricted food intake on gains made per unit of food eaten is shown by the following figures:

*Gain per Gm. of Food Eaten.*

| Protein fed. | Restricted intake | Protein fed. | Unrestricted intake |
|--------------|-------------------|--------------|---------------------|
|              | per cent | gm.     | per cent | gm.     |
| Lactalbumin. |          |         |          |         |
| 16.0         | 16.2     | 0.33    | 16.2     | 0.32    |
| 11.1         | 10.3     | 0.24    | 10.3     | 0.27    |
| 9.2          | 7.9      | 0.20    | 7.9      | 0.24    |
| Casein.      |          |         |          |         |
| 21.0         | 17.4     | 0.23    | 17.4     | 0.30    |
| 17.4         | 12.0     | 0.24    | 12.0     | 0.27    |
| 9.2          | 9.3      | 0.19    | 9.3      | 0.14    |
| Edestin.     |          |         |          |         |
| 17.9         | 17.9     | 0.27    | 17.9     | 0.25    |
| 12.4         | 12.4     | 0.16    | 12.4     | 0.20    |
| 9.2          | 9.6      | 0.10    | 9.6      | 0.13    |

Comparing the gains made on diets containing similar percentages of each protein when the food intake was restricted, with those made when it was unrestricted, it is seen that with only three exceptions these were greater under the latter conditions of feeding. Economy of food can be effected only by supplying the young animal with as much as it will eat; economy of protein only by reducing the nutritive ratio below that at which the normal rate of growth can be maintained.

Economy in nutrition during growth depends upon a correct adjustment between the proportion of protein and the total energy supplied: furthermore, the optimum of protein is determined not only by the absolute amount furnished, but also by its quality.
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CORRECTION.

On page 226, Vol. XXXVII, No. 2, February, 1919, line 12, for 20 per cent more food, read 20 per cent less food.