XL. THE DIETARY VALUE OF POTATO PROTEIN.

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IN a previous paper [Hartwell, 1925] it was shown that rats fed on a diet of potato, butter and salt mixture grew slowly and exhibited loss of fur. It was suggested that the use of new potatoes instead of old ones might lead to better results, and therefore further experiments on the same lines were started. Some years previously McCollum, Simmonds and Parsons [1918] fed young rats on potato supplemented in various ways. The potato used by these workers was dried, and ground up, so that the experiments are not strictly comparable with those described in this paper, where the object was to feed the potato in a form in which it is taken by man. McCollum and his co-workers found that the potato was poor in calcium, sodium and chlorine; therefore to guard against a shortage of any mineral constituents, salt mixture [Hartwell, 1922] was used in the diet described in this paper. Potatoes appear to contain quite large quantities of vitamin B [Steenbock and Gross, 1919] and Osborne and Mendel [1920, 1] find that there is no appreciable difference between old and new potatoes in respect of this factor. With regard to vitamin A, there appears to be some difference of opinion. Steenbock and Gross [1919] found that one lot of potatoes contained sufficient fat-soluble vitamin to support growth in young rats, while another sample contained none. This discrepancy in results must surely be due to some difference in technique not realised in this earlier work. Osborne and Mendel [1920, 2] find that the potato as a whole cannot be entirely devoid of fat-soluble vitamins. It seemed, therefore, safer to give butter fat in the diet and thus to guard against any possible deficiency. Incidentally the fat was useful for increasing the calorie value of the food.

Experimental.

Diet. The diet consisted of potato, butter, salt mixture and water. The potatoes were boiled in their skins and then peeled and mashed. The proportions used were 100 g. boiled potato, 1 g. salt mixture, 5 g. butter and 25 cc. of water to make a stiff paste. Food was given *ad lib.* and distilled water was provided in the usual water bottles.

Exp. 1. Effect of the potato diet during growth. 12 young rats, 6♀ + 6♂, were given the potato diet from weaning (3 weeks and 2 days). The experiment lasted just over 3 months, from April 14 to July 21, 1924. Old potatoes were used. The average ♂ curve is given in a previous paper [Hartwell, 1925].

Exp. 2. Effect of the potato diet during growth, gestation and lactation. This experiment was the same as Exp. 1, except that new potatoes were used instead of old ones and the feeding was continued for a longer period (August 18, 1924–May 21, 1925).

Exp. 3. Effect of the potato diet during lactation only. Six stock does were fed on a mixed diet of kitchen scraps and bread and milk until litters were born, after which they were given the potato diet.

Exp. 4. Effect of the potato diet supplemented with bread, during lactation only. Six stock does similar to those used in Exp. 3 were given a diet consisting of 15 g. potato diet, 15 g. bread and 21 cc. water mixed well together. The feeding was started as soon as possible after the birth of the litter.

Method. In Exps. 1 and 2 the method used was that described in a former paper [Hartwell, 1926]. For Exps. 3 and 4 the technique has been fully described in earlier papers on mammary secretion.

RESULTS AND DISCUSSION.

Growth. In Exps. 1 and 2 most of the young rats grew, but very slowly compared with control animals. Two of the males showed maintenance of weight, but hardly any growth. Their condition was poor, and their fur came out badly [Hartwell, 1925]. It eventually grew again, but the coats were always thin. Rats fed on new potatoes appeared no better than those fed on old ones. In Exp. 2 the animals had an old look at a comparatively young age. That this frequently occurs when rats are fed on a poor diet has been shown by McCollum, Simmonds and Parsons [1918]. The young animals were particularly susceptible to cold, and, as shown in Fig. 1, several of them died after a short period on the potato diet. *Post mortem* the lungs were found to be badly affected in all cases. McCollum, Simmonds and Parsons [1918] fed rats on diets consisting largely of potato, and state that "growth took place slowly or not at all, individual animals shewing somewhat different capacity to make use of the diet." The results described here are quite in agreement with this statement. These observers gave 7–8 % of potato protein in the food (using dried potato), and the diet used by me could not have contained more than 7.6 % of protein. A possible explanation of the failure of growth in some animals is the low protein content, which may be borderline, and hence some of the rats were unable to adjust their metabolism to this low level of intake. That the rats were in fairly good health is shown by the rapid growth and improvement in condition produced by changing the diet. In Exp. 1 the food was changed to a mixture of 15 g. bread, 6 g. food casein [Hartwell, 1922], 0.4 g. salt mixture, 1.5 g. butter and 45 cc. of 3 % marmite.

After 10 days the animals were in good condition; the fur was thick and glossy and they had grown much more rapidly.

Fig. 1. Growth curves of young rats fed on a diet of potato, butter, salt mixture and water.

----- Diet changed to bread, food casein, salt mixture, butter and marmite.

Maintenance. No experiments were made to test the efficiency of potato protein as regards maintenance, but it seems reasonable to suppose that a diet which provides for growth (and reproduction), at any rate in some animals, is adequate for maintenance. Rose and Cooper [1917] found that a woman was able to maintain nitrogenous equilibrium for 7 days on a diet of potato, sugar, and agar-agar; they conclude, therefore, that the nitrogenous compounds of the potato possess a high nutritive efficiency.

Hindhede [1913] considers that "vegetable foodstuffs, and potatoes in particular, are considerably better digested than animal." He calculates (from the experiments of Constantinidi on man) that of 3000 calories in potatoes and fat, only 2 % go to waste in the faeces, while in meat and fat, or milk, the loss is 5 %.

Reproduction. No young were born until the does were about 5½ months old, while stock animals produce and rear their young as early as 3 months. An explanation of this probably lies in the fact that the rats on the potato diet were very small for their age and of poor weight. The breeding results were as follows:

- Rat 1¹. Produced 3 litters.
 - 1. 3+1 dead—all eaten 11th day.
 - 2. 1+7 dead—dead 6th day.
 - 3. 7+4 dead—3 reared—average weight at 21 days 36.3 g.
- Rat 2¹. Produced 3 litters.
 - 1. 1+3 dead—dead 2nd day.
 - 2. Born dead.
 - 3. Born dead.
- Rat 3. Died before any young born.
- Rat 4. Produced 2 litters.
 - 1. 3—eaten 3rd day.
 - 2. Eaten 2nd day.
- Rat 5. Died before any young born.
- Rat 6. Died at birth of 1st litter.

The rats fed exclusively on the potato diet were not sterile, but the food must be regarded as very unsatisfactory for gestation, because so many of the young were born dead. The noticeable failure to rear the young (even when a good diet, such as bread and milk, was given to the mother rat after their birth) suggests that those which were alive were weakly. All the young were of low weight at birth. The low percentage of protein in the diet may account for these poor results.

Lactation. Exp. 2 gave no results in this respect; only one litter was reared and the mother had been given bread and milk.

Exp. 3 showed that it was possible for the rat to rear her young when she was fed on the potato diet during lactation. Each rat was allowed to keep six of her babies, but only one animal succeeded in bringing up the whole litter. The growth curve of these is shown in Fig. 2. The other rats lost two or three of their young at different stages of lactation. From Fig. 2 it is obvious that the mother rat lost weight during lactation. This loss of weight occurred in all cases. The young grew slowly, and were below normal weight at weaning; their fur was thin and poor. The general condition of the young was similar to that obtained when the mother rat was fed on a diet of bread, butter and salt mixture, but with the bread diet the weight curve of the young was slightly better, though the mother rat lost weight as badly. (1182 in Fig. 2 is put in for comparison.)

¹ Bread and milk diet given after the birth of the litter.

In Exp. 4 bread was added to the potato diet, and, as seen from the figure, the growth of the young rats was improved. Their general condition also was better, but they were still far below average weight, being only 23–24 g. at weaning instead of approximately 40 g. The supplementing of the potato and bread proteins is in agreement with the work of McCollum, Simmonds and Parsons [1921].

These experiments show that potato as the sole source of protein in the diet is not adequate to meet the needs of the rat. Is it the *quality* or the

quantity of the protein which is at fault? McCollum, Simmonds and Parsons [1918] consider that it is the *quality* which is the limiting factor. These workers used other diets "similar in every respect except that a portion of the carbohydrate was replaced by the purified protein casein." This modification led to rapid growth of the animals, but the author does not consider this a proof of any inadequacy in *quality*, because from the statement quoted above it is clear that a greater *quantity* of protein was used. In the experiments described in this paper, the percentage of protein in the food was only about 7.6, much too low to expect good growth. Therefore the fact that growth and even reproduction took place seems to suggest that the potato protein is of good quality and it is the insufficient amount which caused the poor results. In support of this hypothesis there is the work of Rose and Cooper [1917] and the observations of Hindhede [1913] previously quoted. Onslow [1920] states that potatoes contain a globulin, tuberin; such proteins are regarded as being of good quality. Further, tyrosine, lysine and leucine are said to be found in the tubers [Onslow, 1920]. According to Rose and Cooper [1917] only 63 % of the potato nitrogen is in the form of protein, but the animal organism is capable of using amino-acids, and tyrosine is an essential member of this group. A watery, protein-free extract of potato gives a well-marked Millon's reaction.

The calorie value of the potato diet was equivalent to that eaten by other rats giving normal growth curves.

SUMMARY.

1. Potato protein provides for growth in some rats but the rate is very slow. Other rats fail to grow on the diet.
2. Reproduction takes place on a diet of potato, butter, salt mixture, and water, but many of the young are born dead, and hardly any of them are reared.
3. The rat can rear her young on the above diet (if she is given better food during gestation), but the babies are undersized and have poor coats; the mother rat loses weight during lactation.
4. The addition of bread to the potato diet during lactation results in improved growth and condition of the young rats, but the mother still loses weight.
5. It is suggested that the *quantity* rather than the *quality* of the potato protein is responsible for the slow growth.

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