XCIV. A NOTE ON THE BLOOD-SUGAR LEVELS OF RATS FED WITH COMPLETE DIETS AND DIETS DEFICIENT IN VITAMIN B

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INTRODUCTORY.

Based on the observation that the addition of carbohydrate to a beri-beri-producing diet fed to pigeons hastened the appearance of this disease, Funk [1914] suggested that the anti-beri-beri vitamin plays some part in carbohydrate metabolism. In the same year Funk and v. Schönborn [1914] described a hyperglycaemia and a shortage of glycogen in the livers in pigeons suffering from beri-beri.

In 1919 McCarrison stated that the absence of “anti-neuritic” food factors from the diet leads to an increase in the weight and adrenaline load of the adrenal gland, and to a state of acidosis due to the imperfect metabolism of carbohydrates and the acid fermentation of starches [1919]. On the basis of McCarrison’s results, Funk [1920] pointed out that increased adrenaline in the circulation was probably responsible for the hyperglycaemia which he had obtained in another series of beri-beri pigeons (bled out under A.C.E. mixture). Funk’s figures show in this experiment a higher glycogen content in the “beri-beri” livers than in the “normal control” livers—a result opposed to that which he and v. Schönborn had previously found. (See also the work of Tschkerkes [1922] in this connection.)

From a study of the respiratory quotient of rats fed with diets deficient in vitamin B, Mattill [1923] concluded that there was no interference with the process of glucose combustion, traceable to this deficiency.

Since most of these observations were made on animals whose diets were unbalanced in other respects besides the lack of vitamin B, we thought it advisable to re-investigate the question of carbohydrate metabolism in rats fed on a well-balanced diet, deficient only in vitamin B. Our observations come under the following categories:

I. Blood-sugar levels in rats fed with complete diets and with diets deficient in vitamin B.

(a) 1–3 hours after feeding (i.e. the “resting” level).
(b) 24 hours after feeding (basal level).
(c) After a glucose meal.
(d) After a starch meal.
II. Glycogen content of the livers of rats fed with complete and with vitamin B-deficient diets, for different periods.

(a) 1–3 hours after feeding.
(b) 24 hours after feeding.

III. Food intake of rats fed with the diets used throughout this work.

EXPERIMENTAL.

Adult rats of 100–150 g. body weight were employed. The rats were kept several weeks in the laboratory before being used in the experiments, and those showing abnormal behaviour were discarded. The diet of the normal control animals was as under:

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>100 g.</th>
<th>100 g.</th>
<th>10 g.</th>
<th>10 g.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice starch</td>
<td></td>
<td></td>
<td>Lemon juice</td>
<td></td>
</tr>
<tr>
<td>Caseinogen</td>
<td>40</td>
<td>Salt mixture</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Butter</td>
<td>20</td>
<td>Water</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>Yeast extract</td>
<td>10</td>
<td></td>
<td></td>
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</tbody>
</table>

In the vitamin B-deficient diet the yeast extract was omitted and the caseinogen was purified by extraction with alcohol (boiling). In a later experiment meat extract (free from vitamin B) was added to this diet in an endeavour to match the flavour of the control diet. The vitamin B-deficient diet fed to an animal of 100 g. body weight produced coma in about 50 days [cf. Drummond, 1918].

Glycogen was estimated by the method of Pflüger, the livers being dropped into boiling alcoholic potash immediately after the death of the animal. For the estimation of blood-sugar the method of MacLean [Gardner and MacLean, 1914] was employed, necessitating 0-2 cc. of blood for an estimation. The samples were obtained from the brachial artery after stunning the animal, the use of anaesthetics being avoided. One sample of blood only could be taken from an animal in this way. Hence for the construction of the curves given in this paper 5–10 rats were used to obtain each point in a curve.

Blood-sugar levels.

The blood-sugar levels in rats fed with the vitamin B-deficient diet for different lengths of time are shown in Fig. 1. As is seen, the results indicated nothing abnormal in the deficient animals until the stage of the final collapse, when the blood-sugar fell to a starvation level. Contrary to Funk's experience with pigeons, there is no evidence of hyperglycaemia.

For the purpose of the feeding experiments contemplated, it was necessary to establish the basal level of the blood-sugar of the rat. It was found that a 24-hour fast brought down the level to a very steady basal level of 0-09%. The simultaneous administration of adrenaline produced no lower results (Table I).
Table I. Blood-sugar levels after a 24-hour fast.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Individual values (% glucose)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal rate</td>
<td>0.08, 0.09, 0.08, 0.10, 0.09, 0.10, 0.09</td>
<td>0.09</td>
</tr>
<tr>
<td>Normal rate with simultaneous injection of 0.1 mg. adrenaline (intraperitoneal)</td>
<td>0.08, 0.09, 0.09</td>
<td>0.087</td>
</tr>
<tr>
<td>Rats 40 days on deficient diet</td>
<td>0.12, 0.13, 0.095, 0.13, 0.11, 0.11, 0.11</td>
<td>0.115</td>
</tr>
</tbody>
</table>

The blood-sugar values for the vitamin B-deficient rats are seen to be higher and more erratic than the corresponding figures for the normal rats. This may be due to absorption from the atonic intestine which, as one of us has shown [Gross, 1924] is subject to stasis in this condition. The livers of all these rats were empty of glycogen.

![Fig. 1. The effect of vitamin B-deficient diet on the blood-sugar level of the rat. Note.—The final value coincides with the basal level (i.e. level after 24 hours' fast).](image)

Having established the basal blood-sugar of the rat when fed on normal diet and a diet deficient in vitamin B, the effect of a glucose meal was observed. The animals, after a 24-hour fast, were given a meal of glucose (with the aid of a stomach tube) the dosage being regulated to 500 mg. per 100 g. body weight. The animals were killed after periods of 15, 30, 45 and 60 minutes, and their blood-sugar estimated. The vitamin B-deficient rats had been 36–40 days on the deficient diet. The results are shown in Fig. 2.

When allowance is made for the lower basal level of the normal rat there is no significant difference between the two curves. Attempts to compare the rates of absorption of starch by the same method failed owing to the flatness of both curves.

A definite effect of vitamin B deficiency was found in the glycogen content of the livers of the animals (estimated by Pflüger's method). After a 24-hour fast the livers were empty of glycogen in all cases, but the values for rats
taken straight from the cage showed a continued decline as a result of the deficient diet (Fig. 3). This result is in agreement with the observation of Funk and v. Schönbom [1914] that the livers of pigeons fed with a beri-beri-producing diet are poor in glycogen.

![Diagram 2: Blood-sugar curves following glucose meals.](image)

![Diagram 3: Glycogen content of livers of rats fed on a vitamin B-deficient diet.](image)

The condition of the vitamin B-deficient rat is in many ways not unlike that producible by underfeeding. Indeed the animal almost invariably is in a fasting condition at the end. A metabolism experiment performed with
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intent to control this point showed that the vitamin B-deficient rat ate only from 50–60% of the food taken by animals of the same weight fed with a complete diet. This fall in the food intake occurred practically from the first day on the diet. On the supposition that the insipid taste of the diet (due to its lack of yeast extract) was in part responsible for this lower food intake, an endeavour was made in a parallel experiment to restore the flavour with a meat extract known to be free from vitamin B. This, however, had no appreciable effect. Table II compares the appetites of the rat for the normal control diet (a), the vitamin B-deficient diet (b), and the latter diet flavoured with meat extract (c). Each figure is the mean for three rats over the first 12 days on the diet.

Table II. Amounts (dry weight) of food eaten per day per 100 g. rat.

<table>
<thead>
<tr>
<th></th>
<th>(a) Deficient diet + yeast extract</th>
<th>11.1 g.</th>
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<tbody>
<tr>
<td>(b)</td>
<td>Deficient diet</td>
<td>6.3</td>
</tr>
<tr>
<td>(c)</td>
<td>Deficient diet + meat extract</td>
<td>6.0</td>
</tr>
</tbody>
</table>

It would seem likely from these figures that vitamin B has a direct stimulating influence on the appetite of the rat, apart from other functions. Wright [1921] has shown that the addition of vitamin B to a diet deficient in vitamins A and B (fed to rats) increases peristalsis and stimulates appetite and growth.

SUMMARY.

The normal and basal blood-sugar levels of rats fed on complete and vitamin B-deficient diets have been ascertained.

The rate of absorption of glucose from the alimentary tract has been shown to be unaffected by vitamin B deficiency.

A gradual removal of glycogen from the liver has been shown to follow the elimination of vitamin B from the diet of the rat.

It has been demonstrated that meat extract fails to stimulate the appetite of the rat when substituted for yeast extract in the diet as the sole flavouring principle. It is suggested that there is a causal relationship between the vitamin B content of the diet and the food intake of the rat.

In conclusion we desire to record our gratitude to Prof. J. C. Drummond for much valuable help and encouragement.

REFERENCES.

Gardner and MacLean (1914). Biochem. J. 8, 391.
Tscherkas (1922). Biochem. Z. 133, 75.
Wright (1921). Lancet, ii, 921.