THE INFLUENCE OF A VITAMINE-FREE DIET ON THE CARBOHYDRATE METABOLISM.

By CASIMIR FUNK and Count ERWIN v. SCHÖNBORN.

(From the Department of Chemical Physiology, Cancer Hospital, Research Institute, London.)

Some time ago one of us[1] found that the addition of carbohydrates to a vitamine-free diet hastened the outbreak of beriberi. These experiments suggested that the addition of carbohydrates necessitates a greater use of the vitamine stock of the body and therefore rendered it probable that the vitamine plays an active part in the carbohydrate metabolism. The physiological role of the vitamines in the animal economy being unknown, it seemed advisable to extend the study in this direction and the present paper is a preliminary inquiry.

Pigeons were chosen for the experiments. We have determined both the normal glycogen content of the liver and the blood sugar on normal diet. To study the influence of the vitamine-free diet in varying proportions we have used five batches of pigeons which were fed artificially on different artificial food mixtures. The diet consisted of caseinogen, fat, sugar, starch and salts. The first diet was one containing all the ingredients, the second diet was free from sugar, the third free from fat, the fourth free from starch, and the last diet was entirely free from carbohydrates. The animals, all of which had the initial weight of 280 grms., were given these diets in the form of pills and were killed mostly after 14 days. The glycogen was estimated in the liver according to the usual methods and the blood sugar following the method of Michaelis and Rona and titration of the sugar following Bertrand's method. We shall see from the experiments that there was a marked disturbance of the carbohydrate metabolism, namely a high grade hyperglycæmia in cases of the diets containing a large proportion of carbohydrates. We have attempted in a few cases to correct this

[1] Casimir Funk. *Ztsch. f. physiol. Chem.* LXXXIX. p. 373. 1914. *Ibid.* p. 378.

disturbance by an administration of vitamine from yeast. The number of the experiments are not sufficient to allow any definite statements to be made, but they tend to show that the addition of vitamine renders the carbohydrate metabolism more normal.

12·5 gms. of the food mixture was given daily to each pigeon throughout all experiments.

Pigeons on normal diet.

	Liver			Blood			
	Weight	Glycogen	%	Weight	Sugar	%	
1.	6·6	0·051	0·77	11·0	0·01	0·09	
2.	5·5	—*	—	12·0	0·01	0·08	
3.	7·3	0·051	0·70	14·1	0·014	0·10	
4.	7·5	0·102	1·33	—	—	—	
5.	5·2	0·121	2·3	12·1	0·017	0·14	
6.	7·9	0·061	0·77	12·7	0·013	0·11	Nematodes in liver.

* Glycogen estimation lost.

EXP. I. *Full artificial diet.*

omposition of the diet:—Caseinogen 12 p.c.
Starch 28 ,,
Fat 28 ,,
Sugar 28 ,,
Salts 4 ,,

	Liver			Blood			
	Weight	Glycogen	%	Weight	Sugar	%	
1.	5·5	0·039	0·71	9·5	0·017	0·18	Killed after 14 days.
2.	6·1	0	0	12·6	0·016	0·12	
3.	4·8	0·033	0·69	9·3	0·016	0·17	

EXP. II. *Carbohydrate-free diet.*

Diet—Caseinogen ... ... 12 p.c.
Fat ... ... 42 ,,
French chalk to make up pills 42 ,,
Salts ... ... 4 ,,

	Liver			Blood			
	Weight	Glycogen	%	Weight	Sugar	%	
1.	4·8	0·022	0·46	11·3	0·021	0·19	Killed after 14 days.
2.	4·0	0·011	0·27	9·5	0·025	0·26	
3.	4·7	0·011	0·25	12·0	0·022	0·18	

EXP. III. *Starch-free diet.*

Diet—Caseinogen 12 p.c.
Sugar 42 ,,
Fat 42 ,,
Salts 4 ,,

	Liver			Blood			
	Weight	Glycogen	%	Weight	Sugar	%	
1.	2·8	0·027	0·76	5·5	0·012	0·22	Killed after 14 days.
2.	3·5	0·010	0·29	9·5	0·020	0·21	
3.	2·7	0·027	1·0	11·3	0·022	0·20	

Exp. IV. *Fat-free diet.*

Diet—Caseinogen 12 p.c.
Sugar 42 ,,
Starch 42 ,,
Salts 4 ,,

	Liver			Blood			
	Weight	Glycogen	%	Weight	Sugar	%	
1.	5·8	0·325	5·6	10·9	0·010	0·09	Killed after 14 days. Nematodes in liver.
2.	7·1	0·255	3·6	—	—	—	
3.	10·1	0·950	9·4	—	—	—	
4.	3·0	0·027	0·9	8·0	0·012	0·15	
5.	3·5	0·078	2·2	8·3	0·018	0·21	
			The same diet with addition of vitamine.				
	4·2	0·016	0·4	6·6	0·015	0·23	

Exp. V. *Sugar-free diet.*

Diet—Caseinogen 12 p.c.
Starch 42 ,,
Fat 42 ,,
Salts 4 ,,

	Liver			Blood			
	Weight	Glycogen	%	Weight	Sugar	%	
1.	4·1	0	0	9·8	0·035	0·36	Killed after 14 days.
2.	3·7	0	0	11·5	0·035	0·30	
3.	4·5	0·006	0·01	11·0	0·029	0·26	
4.	4·6	0	0	6·3	0·015	0·24	Killed after 12 days.
5.	5·9	0	0	4·5	0·013	0·29	
6.	6·8	0	0	13·0	0·017	0·13	After 13 days had beriberi.

The last pigeon developed beriberi, the question whether the blood sugar diminishes in an attack of beriberi will be especially investigated.

			The same diet with vitamine addition.				
1.	4·7	0·033	0·7	11·6	0·023	0·20	12 days.
2.	4·4	0·022	0·5	8·7	0·017	0·19	13 days.
3.	4·9	0·033	0·68	11·4	0·021	0·18	

In all the experiments except those of Exp. V in which vitamine was given the weight of the animals dropped (in some cases by 20 %).

SUMMARY.

1. Pigeons kept on vitamine-free diet develop a tendency to hyperglycæmia with diminution of the glycogen of the liver.

2. This hyperglycæmia is especially marked in the case of sugar-free diet, which is followed by an entire disappearance of liver glycogen.

3. The addition of vitamine from yeast to the latter diet produces, in the three experiments made, a very marked formation of glycogen in the liver and a diminution of the sugar in the blood. Vitamine thus seems to have a distinct influence on the glycogen metabolism.

4. In case of the fat-free diet the glycogen content of the liver is increased.