Effect of Proteins on the Blood Glucose Levels

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The yield of glucose obtained in protein metabolism is approximately 50 per cent of the weight of ingested protein (Reilly, Nolan and Lusk 1898,[1] Ringer and Lusk 1910,[2] Janney and Csonka 1915,[3] Janney 1916[4]). Janney (1915)[5] found that with isolated proteins the production of glucose varied from 48 per cent to 80 per cent, whereas Bancroft and Drury (1951)[6] in the phlorizinized-depancreatized dog observed a 90 to 95 per cent conversion of protein to glucose. The liberation of glucose into the blood stream during protein metabolism is slower than the liberation of an equivalent amount of glucose derived from glucose and carbohydrate foods, shown by Conn and Newburgh (1936)[7] in experimental studies with fifteen diabetic patients. Pollack and Dolger (1938,[8] 1939[9]) suggested the diabetic patients take 50 per cent or more of the daily protein allowance at the evening meal in order to buffer the tendency toward decreasing blood sugar concentration during the night. Gubbay (1951)[10] found that in feeding diabetic patients with protein, the slow conversion of protein to glucose caused minor changes in the blood sugar of well controlled diabetic patients.

The purpose of the present study was to investigate the changes in level of blood glucose, after feeding normal and diabetic human subjects with various amounts of isolated plant proteins, gelatin and egg white. Eighty normal and eight diabetic volunteers were the subjects of the present study. A total number of 176 experiments were performed studying the effect of the whole egg white, gelatin, and proteins prepared from lentil, oat, wheat and pea bean. The details of the experiments and the results obtained are described in the present paper.

MATERIALS AND METHODS

Preparation of plant proteins. After grinding the plant food, the fat was extracted in a Soxhlet's apparatus. The residue was suspended in a 10 per cent aqueous solution of sodium chloride. The mixture was stirred for several hours and allowed to settle. The clear water solution was decanted. A fresh 10 per cent sodium chloride solution was added, the solution stirred, and again decanted. The above process was repeated until no appreciable amount of proteins could be detected in the salt solution. The saline layers were combined and filtered in order to remove impurities. Acetic acid was added to the filtrate in a final concentration of about 80 mM. The resulting mixture was heated to the boiling point. After cooling, the precipitated protein was filtered and washed with water. The protein was collected and dried in an oven at 60°C.

Digestibility of proteins. The digestibility of the obtained proteins was determined by Steudel's method (1935).[11] The materials to be tested were examined for water, ash, nitrogen and caloric content (original values). The materials digested in vitro and the undigested residue were again submitted for determination of ash, nitrogen and caloric content. The calculations were referred, in both cases, to 100 gm. of the original substance and the difference of both results yields the utilized part of the sample tested. The samples (100 gm. in 1,000 ml. of water) were digested with the different enzymes: Pepsin 0.5 gm. 8 ml. concentrated HCl, pancreatin 0.4 gm. 2 gm. sodium carbonate and diastase 0.05 gm. made slightly alkaline with sodium carbonate. For this purpose they were left in 1,000 ml. of water saturated with toluene for forty-eight hours in an incubator at 37° C. with frequent stirring. The remaining residue after centrifuging comprises the undigested part of the material.

The changes in the glucose content of the subject's blood after feeding the individual protein was investigated as follows: After fasting twelve hours the subjects were fed a known amount of the individual protein. The glucose content of the subject's blood was determined beforehand using the Hagedorn-Jensen method (1923).[12] Duplicate determinations were made at intervals of three and a half and five hours after feeding the proteins. The subjects remained in a reclining position after the intake of the proteins without additional nutriment. Goth, Bencze and Lengyel (1952)[13] used the same method in

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studying the dietary effect of egg whites on the blood glucose levels of humans with an adrenal cortex insufficiency.

Any change of less than 10 mg. per cent in the glucose of the blood was considered negligible.

EXPERIMENTAL RESULTS

The subjects of the experiments were volunteers of the Evangelismos Hospital of Athens, Greece. The average age was 35 (20 to 50). The diet served by the hospital was generally the same for all the subjects. The test started in the morning about 8:30 a.m. and ended five hours later. The subjects who were tested with the individual plant protein were tested again the next morning under the same conditions, with 20 gm. of egg white dried at 60° C. This was used as a standard control for all the experiments. Eight volunteer diabetic patients were tested under experimental conditions just described. For a week previous to the experiment they were not treated with insulin or other drugs. A glucose tolerance test was performed on each of these patients to confirm the diagnosis of diabetes. Control experiments were performed with 20 gm. dried egg white.

The analytical data of the obtained results for the tested proteins, for both normal and diabetic subjects, are described as follows:

Egg white. Feeding 14 gm. of egg white there was no increase in blood glucose. Upon increasing the amount of egg white from 17 gm. to 23 gm., an increase in glucose of 10 to 30 mg. per 100 ml. of blood was observed after three and a half and five hours; in some individual cases the glucose remained unchanged. The amount of 20 gm. of egg white was selected as a standard control for comparing the obtained results after feeding the subjects with plant proteins. In a total number of sixty-three tests with normal subjects feeding 20 gm. of egg white, (tables 1-4), the average increase of the glucose was 14.6 mg. per 100 ml. of blood, with individual increases of 10 to 40 mg. per cent. A similar result was obtained feeding eight diabetic subjects with 20 gm. of egg white. The average increase after five hours was 12.3 mg. per cent (table 4).

Oat protein. Normal subjects were fed 15 to 25 gm. oat protein, and a decrease or unchanged blood glucose was observed after three and a half and five hours. After feeding 30 to 36 gm. there was an increase of 10 to 40 mg. in glucose per 100 ml. of blood. The average increase after feeding five subjects with 36 gm. oat protein was 14.4 mg. per cent. In three cases the glucose remained unchanged (table 1). Oat protein was tested in three diabetic subjects by feeding 13 gm. and 20 gm. oat protein. In all cases there was a decrease in blood glucose (table 4).

Wheat flour protein (gluten). The protein fed to thirteen normal subjects was the gluten of the wheat. The subjects were fed 15 to 30 gm. gluten and no increase of the blood glucose was observed. After feeding 32 to 40 gm. of gluten, an increase in glucose of 10 to 40 mg. per 100 ml. of blood was obtained. The average increase by feeding four subjects with 40 gm. was 21.9 mg. (table 1). Four diabetic subjects were fed 20 to 35 gm. of protein. An increase of blood glucose was observed three and a half hours after feeding 35 gm. of gluten (table 4).

Lentil protein. The subjects fed 20 to 55 gm. of lentil protein showed no increase in blood glucose. Feeding 64 gm. to 70 gm. an increase of glucose was observed in the subject's blood; in four cases there was no change in glucose. Four subjects fed 70 gm. lentil protein showed an average increase of 16.5 mg. per 100 ml. of blood (table 2). Diabetics were not tested with lentil protein.

Pea bean protein. Nineteen subjects were fed with pea bean protein. It was necessary to feed about four times as much pea bean protein as egg white so that an increase in blood glucose could be obtained. The average increase, feeding three subjects with 78 gm. pea bean protein, was 18.6 mg. per 100 ml. of blood (table 3). In one case, feeding the diabetic subject with 25 gm. of pea bean, there was no change in glucose levels.

Gelatin. Gelatin fed in seven normal subjects from 15 to 30 gm. showed no increase in blood glucose.

The results suggest, as is shown in tables 1 to 4, that the amount of protein required to produce an increase in level of blood glucose in normal subjects, varies with the protein employed. Seventeen grams to 23 gm. egg white seems to be enough to produce an increase, whereas for a similar result 30 to 36 gm. of oat protein are necessary, 32 to 40 gm. of wheat (gluten) protein, 64 to 70 gm. for the lentil protein, and 72 to 78 gm. for the pea bean protein. The gelatin tested in the amount of 30 gm. showed no increase in blood glucose.

The digestibility of the tested proteins, determined with Steudel's (1935)[11] method, was found as follows: Egg white, 100; Oat protein, 90; Wheat flour (gluten), 91; Lentil protein, 86; Pea bean protein, 80.

DISCUSSION

Determination of the glucose in the blood of normal and diabetic human subjects, three and a half and five hours following the ingestion of different proteins, suggests that egg albumin has the highest rate of conversion to glucose followed by oat protein, wheat protein (gluten), lentil protein, and pea bean protein. This may

TABLE 1

Effect of oat and wheat flour protein on the blood glucose

Dose gm.	Test substance: Oat protein mg. glucose in 100 ml. blood 0 hr.	3½ hr.	5 hr.	Mean change per dose	Egg white control (20 gm.) mg. glucose in 100 ml. blood 0 hr.	3½ hr.	5 hr.	Mean change per dose
15	86	101	86		90	90	100	
"	79	69	79	1.2	76	98	106	
23	82	82	82		78	118	108	
"	100	90	90		97	97	112	
"	67	77	77	0.0	78	103	98	
30	78	105	78		86	86	86	
"	116	116	116		98	118	108	
"	79	89	79	6.2	83	110	110	
36	86	113	124		79	94	94	
"	96	96	86		106	106	106	
"	78	95	95		69	94	89	
"	78	100	88		78	105	105	
"	97	124	97	14.4	86	76	76	16.3
	Test substance: Wheat flour protein							
15	98	98	88		87	77	97	
"	75	75	75		79	109	94	
"	87	97	72	−2.5	76	86	96	
25	106	116	106		97	124	97	
"	115	115	105	0.0	86	101	101	
32	93	93	103		100	110	100	
"	80	70	70		87	87	97	
"	78	78	78		76	106	103	
"	83	98	83	0.6	98	98	98	
40	92	116	114		79	119	114	
"	87	87	77		83	83	83	
"	85	117	117		96	111	111	
"	78	118	93	21.9	85	107	117	14.2

TABLE 2

Effect of lentil protein on the blood glucose

Dose gm.	Test substance: Lentil protein mg. glucose in 100 ml. blood 0 hr.	3½ hr.	5 hr.	Mean change per dose	Egg white control (20 gm.) mg. glucose in 100 ml. blood 0 hr.	3½ hr.	5 hr.	Mean change per dose
20	97	97	82		83	113	108	
"	106	116	106	−1.2	97	97	107	
35	89	79	79		76	76	96	
"	83	93	83	−2.5	87	87	77	
45	78	88	78		78	110	105	
"	94	104	79		86	126	116	
"	116	106	116	−0.8	93	83	103	
55	86	91	76		76	136	116	
"	95	95	95	1.2	89	104	104	
64	76	91	86		85	70	90	
"	96	106	96		106	106	106	
"	78	78	78		76	106	96	
"	89	89	89		83	110	115	
"	82	102	92	3.8	96	106	96	
70	86	126	118		87	92	92	
"	100	100	115		107	107	107	
"	76	94	103		79	106	106	
"	78	78	78	16.5	89	99	89	14.6

TABLE 3

Effect of pea bean protein on the blood glucose

Dose gm.	Test substance: Pea bean protein, mg. glucose in 100 ml. blood, 0 hr.	3½ hr.	5 hr.	Mean change per dose	Egg white control (20 gm.), mg. glucose in 100 ml. blood, 0 hr.	3½ hr.	5 hr.	Mean change per dose
20	86	76	86		75	90	90	
"	82	72	72	−7.5	86	96	86	
30	93	83	103		95	95	105	
"	78	78	78		69	101	96	
"	72	82	72	2.5	78	93	105	
50	103	93	93		95	95	80	
"	97	107	97	−2.5	88	78	88	
60	80	107	80		75	105	105	
"	93	93	83		82	109	97	
"	100	100	100	2.8	92	82	107	
65	85	85	85		79	94	94	
"	86	86	76		80	107	107	
"	75	75	75	1.6	72	104	99	
72	106	106	116		98	108	88	
"	79	79	79		87	72	87	
"	95	95	115	8.3	82	122	114	
78	86	86	106		75	107	107	
"	78	78	88		83	98	93	
"	76	76	91	18.6	78	105	93	14.8

TABLE 4

Effect of various plant proteins on the blood glucose level of diabetics

Protein	Dose gm.	Test substance: Plant protein, mg. glucose in 100 ml. blood, 0 hrs.	3½ hrs.	5 hrs.	Egg white control (20 gm.), mg. glucose in 100 ml. blood, 0 hrs.	3½ hrs.	5 hrs.	Mean change per dose
Oat	13	216	186	176	198	198	198	
"	20	245	235	205	230	230	206	
"	20	182	152	152	167	182	182	
Wheat	20	162	138	132	185	185	185	
"	25	206	191	168	178	183	178	
"	30	166	151	166	160	175	175	
"	35	145	167	155	132	192	164	
Pea bean	25	182	182	182	165	192	192	12.3

be due to the different rate of time required for each protein to liberate glucose into the blood stream and to the fact that the yield of glucose per unit weight of protein varies from protein to protein. There was no significant effect on the blood sugar levels of the tested diabetics, although greater doses of plant proteins are necessary in order to obtain more conclusive results.

Proteins ingested in an impure state with cellulose and other impurities are less digestible than in a pure, very finely divided form (Janney).[5] The amount of water ingested with the protein meal also has an effect on the rate of digestion. However, the conditions of preparation of the tested proteins, and those of the experiments, eliminate the effect of these factors. The test for the blood glucose in periods of three and a half and five hours after ingestion of the proteins also eliminates the possibilities of error from nonspecific factors. Janney (1915)[5] noticed that the glucose excretion reaches its maximum at the second to the third hour after intake of the protein; complete elimination of the glucose occurs by the ninth hour. However, it is true that the proteins used for these experiments are denatured and although they are digestible, their reactions might be different from the equivalent undenatured products. Changes in level of blood glucose were sometimes as great as 40 to 60 mg. per 100 ml. of blood. This is considerably greater than could be explained by experimental error (±10 per cent).

SUMMARY

An increase of glucose in the blood of normal and diabetic human subjects was determined at three and a half and five hours following the ingestion of different proteins. The data suggest that egg albumin has the highest rate of conversion to glucose, followed by oat, wheat flour (gluten), lentil, and pea bean proteins. There was no significant effect on the blood glucose levels of the tested diabetics.

SUMMARIO IN INTERLINGUA

Nivellos de Glucosa del Sanguine in Humanos Normal e Diabetic Post Ingestion de Proteinas Animal e Vegetal

Un augmento del glucosa del sanguine in humanos normal e diabetic esseva determinate 3½ e 5 horas post le ingestion de varie proteinas. Le datos suggere que albumina ab ovos ha le plus alte proratas de conversion in glucosa. Illo es sequite per proteinas ab avena, farina de tritico (glutine), lenticula, e faba sic. Esseva notate nulle significative effecto super le nivellos de glucosa sanguinee in le diabeticos testate in iste studio.

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Somatotypes

Elsewhere we have discussed the question of classification of the body according to "somatotype" and the application of this to nutritional problems.[1, 2] Though it is admitted that there are, in fact, body types independent of body weight and fatness and that this fact ought to be brought into the analysis somewhere, the fact is that no acceptable scheme is yet at hand. Sheldon's[3] "endomorphy" and "ectomorphy" appear to be primarily impure expressions of the obesity-emaciation continuum,[4, 5, 6] while the meaning of "mesomorphy" is uncertain. The fact that Sheldon's somatotypes are related to body fatness and to total body water[7, 8] does not confer any special value to somatotyping; better estimates of these items are available by other means.

From the book *Modern Nutrition in Health and Disease* edited by Michael G. Wohl, M.D., and Robert S. Goodhart, M.D. Philadelphia, Lea & Febiger, 1955, Chapter "Body Weight, Body Composition and Calorie Status" by Ancel Keys, Ph.D., p. 28.

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