A STUDY OF METABOLISM IN A HEALTHY VEGETARIAN

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Recent work in American laboratories especially at Yale and Middletown have tended to upset orthodox calculations regarding the minimal intake and output of nitrogen in man under physiological conditions.

Hutchison¹ in his recent work on Dietetics places the inferior limit of proteid absorption for a healthy adult of average weight as 100 grammes or better 125 grammes which would correspond with an intake of 16 grammes nitrogen, and if nitrogenous equilibrium be established nearly the same quantity ought to be excreted.

Chittenden's² recent book on Physiological Economy shows clearly that men of average weight can live and do active work on much less ; indeed, his results show that, without loss of weight or strength, instead of 16 grammes of nitrogen being the minimal limit one third of that amount, or rather more than 5 grammes, must be accepted.

Before Chittenden's and Atwater's results were published the following case of a healthy adult vegetarian was being observed and investigated by us. The subject of our investigation is below the average weight but still a very vigorous specimen of humanity, and our results in his case tend to show that not only the physiological needs of a human body at rest but undergoing the daily demands of average mental and physical work may be supplied on very much less than 100 grammes of proteid, taken in the form of vegetarian diet.

He had been following this régime for years previously. There was nothing whatever in his appearance or attitude to men and things to

1. *Food and Principles of Dietetics*, 1900, p. 21, et seq.

2. *Studies in Nutrition*, Chas. Scribner & Sons, New York.

brand him as a 'faddist.' Being the editor of a newspaper he took a lively interest in all that was going on. It seemed advisable to ascertain exactly how much nitrogen was being absorbed and excreted and in as far as opportunities allowed this was done pretty systematically and thoroughly during two periods of observation at an interval of two years. Each period lasted for fourteen days. During the first period the urine only was examined. The food was carefully tabulated and weighed for future investigation and a blood count taken.

During the second period after a lapse of two years without any breakdown the same dietary, or as nearly the same as possible, was employed. In this case the nitrogen was estimated not only in urine but in food and faeces too. The blood count and weight were taken at the beginning and end of the experiment.

Our method for estimating the intake of nitrogen was devised to suit the circumstances, and it has been tried and found reliable by Atwater under analogous conditions. It is not at all a trustworthy proceeding nor is it easy to estimate the nitrogen in each component of the diet. So we asked the subject of our experiment to weigh and put aside for laboratory purposes an exact counterpart of everything he ate and drank. This was accumulated for each day separately, the solids in one receptacle the fluids in another. These were then carefully secured in tin vessels and conveyed daily to the laboratory where they were first weighed. The solids were then passed through a mincing machine. The fluids were added. The whole was well pounded and mixed in a large mortar to the consistency of a porridge and from a weighed sample of this the total nitrogen of the intake could easily be ascertained.

EPITOME OF HISTORY

The subject of the experiments was born in July, 1866; he is 5 feet 6 inches in height, and weighs 8 stone 7 pounds; the weight has been fairly constant, having increased by a few pounds during the last twenty years.

Family history good, both parents, and seven other children all living; father has had 'suppressed gout'; mother had two attacks of rheumatic fever.

The subject had swollen finger joints in youth, and was subject occasionally to severe headaches, but otherwise healthy.

He became a vegetarian at twenty to twenty-one years of age, and swelling of joints disappeared in time. At first, he used the vegetable nitrogenous foods freely, but gradually his habits changed as he found more fruit and nuts suited him better, and he now uses legumes very occasionally—perhaps twice or thrice a month.

He has resided for six years (1892-1898) in a tropical climate, two in Ceylon, and four in Siam (Bangkok). He was in perfect health during this period, living an active life, and as a naturalist visited all sorts of places, being interested in termites, which necessitated a good deal of exercise and digging.

On return home he resided in Southport (Lancs.) where probably the hard water coupled with effects of previous tropical residence brought on the only return of gouty symptoms, rheumatic pains, in winter, in chest, arms and left foot. A change of diet to fruit, nuts and brown bread, with absolute abstention from legumes, eggs, tea and coffee, and the use of boiled water only, caused the symptoms to disappear and they have not since returned.

He is not specially athletic, but is fond of walking for study of natural history, he also cycles usually a few miles daily to or from business, and has on holidays done long runs on successive days without much fatigue.

The teeth have always been poor, mastication now better by aid of artificial set.

SUMMARY OF DIET

The following is an indication of the nature of the meals during the 1904 period of observation, the table gives the estimations made in the well-mixed samples of exact counterparts set aside as above described.

July 4th. *Breakfast*—Manhu bread, butter, orange marmalade, coffee, milk, sugar. *Dinner*—Green peas, new potatoes, cherry cake. *Tea*—Manhu bread, butter, cocoa. *Supper*—Shredded wheat, milk, stewed gooseberries. *Exercise*—Rode 30 miles on cycle.

July 5th. *Breakfast*—Manhu bread, butter, marmalade, coffee, milk, sugar. *Dinner*—Green peas, new potatoes, boiled black-currant pudding (pastry, half Manhu and half white flour, cocoanut fat and butter). *Tea*—Bread, butter, cake (half Manhu and half white flour, cocoanut fat and butter, sultanas, raisins), cocoa. *Supper*—Shredded wheat, milk, stewed black currants. *Exercise*—In office all day, very little exercise.

July 6th. *Breakfast*—Bread, butter, marmalade, coffee, milk, sugar. *Dinner*—Butter beans, new potatoes, olive oil, mushroom catsup, boiled black-currant pudding, custard (milk, eggs, butter, sugar). *Tea*—Bread, butter, cake, cocoa, milk, sugar. *Supper*—Shredded wheat, milk, stewed red currants. *Exercise*—About 6 miles cycling.

July 7th. *Breakfast*—Bread, butter, strawberry jam, coffee. *Dinner*—Bananas, cocoanut, custard, stewed red currants. *Tea*—Bread, butter, cake, cocoa. *Supper*—Shredded wheat, milk, stewed red currants, stewed black currants. *Exercise*—In office most of day, very little exercise.

July 8th. *Breakfast*—Manhu bread, butter, marmalade, coffee, milk, sugar. *Dinner*—Bananas, cocoanut, cherries. *Tea*—Bread, butter, cake, tea. *Supper*—Bread, butter, jam. *Exercise*—In office all day, about 2 miles cycling.

July 9th. *Breakfast*—Shredded wheat, milk, jam. *Dinner*—White bread (small roll), butter, tea (about 8 ounces). *Tea*—Manhu bread, butter, cake, tea. *Supper*—Bread, butter, jam, lemon squash (one lemon, sugar, water 10 ounces, soda water 6 ounces). *Exercise*—A good deal of walking in afternoon in town. Also about 3 miles on cycle.

July 10th. *Breakfast*—Bread, marmalade, butter, coffee. *Dinner*—Bananas, cheese, strawberries, cream, sugar. *Tea*—Bread, butter, jam, tea. *Supper*—Bread, butter, cucumber, jam, soda and milk (milk 5 ounces, soda water 5 ounces). *Exercise*—Walked about 7 miles.

August 15th. *Breakfast*—Coffee, milk, sugar, bread, butter, marmalade. *Dinner*—Bananas, cheese, curds (milk turned with rennet), stewed greengages, sugar, pears. *Tea*—Cocoa, milk, sugar, bread, butter, cake. *Supper*—Bread, butter, jam, Burgundy and soda water. *Exercise*—Not much exercise—about 2 miles cycling.

August 16th. *Breakfast*—Coffee, milk, sugar, bread, butter, marmalade. *Dinner*—Green peas, potatoes, olive oil, greengage pie. *Tea*—Cocoa, milk, sugar, bread, butter, cake. *Supper*—Shredded wheat, milk, stewed greengages, sugar. *Exercise*—Cycled about 7 miles.

August 17th. *Breakfast*—Bread, butter, marmalade, coffee, milk, sugar. *Dinner*—Banana, macaroni pudding (baked with eggs, milk, and sugar), stewed greengages. *Tea*—Cocoa, milk, sugar, bread, butter, cake. *Supper*—Bread, butter, coffee, milk, sugar, cocoanut biscuit. *Exercise*—Only exercise was walking between office and home.

August 18th. *Breakfast*—Shredded wheat, milk, stewed greengages. *Dinner*—Spanish nuts grated, bananas, greengage pie. *Tea*—Tea, bread, butter. *Supper*—Shredded wheat biscuit eaten dry. *Exercise*—Only exercise between office and home. Heavy writing all day.

August 19th. *Breakfast*—Shredded wheat, milk, greengages (stewed with sugar). *Dinner*—Bananas, grated cocoanut, milk curd and stewed greengages. *Tea*—Tea, bread, butter, cake. *Supper*—Bread, butter, strawberry jam. *Exercise*—Little exercise.

August 20th. *Breakfast*—Bread, butter, strawberry jam, cocoa, milk, sugar. *Dinner*—Spanish nuts, bananas, melon, sugar. *Tea*—Bread, butter, greengage jam, cake, cocoa. *Supper*—Shredded wheat, milk, Welsh rarebit (cheese, flour, milk, egg, mustard, salt, cayenne, butter). *Exercise*—Walking and standing about good part of the day.

August 21st. *Breakfast*—Shredded wheat, milk, stewed greengages. *Dinner*—Bananas, Spanish nuts, melon, sugar. *Tea*—Bread, butter, raspberry and red currant jam, cake, tea. *Supper*—Shredded wheat, milk, stewed greengages. *Exercise*—Little exercise, but standing all afternoon.

TABLE I
FOURTEEN DAYS' URINE OF 1902 PERIOD

	Vol. in c.c. for 24 hours	Sp. gravity	Urea in grams for 24 hours	Uric acid in grams 24 hours	Total Nitrogen in grams 24 hours	SO ₃ in grams for 24 hours
1	510	1011	5·61	·234	2·856	—
2	510	1021	8·78	·3004	4·712	—
3	567	1020	8·81	·2251	4·286	·673
4	510	1021	9·65	·2282	4·712	·9628
5	510	1018	8·35	·218	4·141	·9363
6	454	1012	6·03	·1277	3·035	·4676
7	397	1036	10·65	·3644	5·558	1·1036
8	425	1029	11·52	·2503	5·822	1·0064
9	794	1016	12·11	·2850	6·431	·697
10	680	1016	9·41	·2522	5·168	·6534
11	624	1017	9·51	·2040	4·742	·7388
12	510	1025	14·69	·2856	7·597	1·3278
13	567	1025	15·37	·3072	7·597	1·3233
14	510	1030	18·01	·3034	8·823	1·4676

TABLE II
ESTIMATIONS OF FOOD AND EXCRETA (URINE AND FAECES) OF 1904 PERIOD

1904 Date	Gross Weight (grms)		Urine in c.c. per 24 hrs.	Total Nitrogen		Spec. grav. of urine	Chlorides as NaCl	P ₂ O ₅ in urine	Ratio of Do. of NaH ₂ PO ₄ Na ₂ HPO ₄	Urea in grms. per 24 hrs.	Uric acid per 24 hrs. in grms.	Iron	
	Food grms. per 24 hrs.	Faeces grms. per 24 hrs.		Food	Faeces							Food	Retained
July 4th-11th :													
Week A. 1st	1023	202	390	5'75	2'20	6'11	1034	—	—	12'6	3'45	—	—
" 2nd	1515	190	630	10'13	2'56	6'79	1019	—	—	11'71	2'87	—	—
" 3rd	1723	310	415	10'89	4'17	5'32	1030	—	—	10'54	2'94	—	—
" 4th	1635	265	475	9'58	3'18	5'78	1025	—	—	11'02	2'41	—	—
" 5th	1230	87	305	6'41	0'87	4'49	1033	—	—	8'50	2'26	—	—
" 6th	960	347	235	5'93	(lost)	4'21	1034	—	—	7'54	1'91	—	—
" 7th	1440	360	280	8'20	3'58	5'01	1033	—	—	9'80	2'45	—	—
Aug. 15th-22nd :													
Week B. 1st	1861	276	630	10'63	3'47	5'85	1019	4'79	1'67	1:2'40	11'71	1'31	0'66
" 2nd	1887	320	860	11'05	3'21	6'59	1018	6'79	1'92	1:1'96	15'48	1'49	0'95
" 3rd	1389	55	750	6'69	9'1	5'79	1018	5'97	1'65	1:2'21	11'47	0'82	0'70
" 4th	1163	238	760	5'78	2'99	5'14	1015	4'62	1'35	1:1'84	9'88	0'45	0'14
" 5th	933	285	320	5'49	2'77	4'73	1031	3'07	1'56	1:1'56	8'29	0'49	0'18
" 6th	1426	192	380	11'54	2'39	6'06	1032	4'55	1'60	1:1'81	11'78	0'68	0'49
" 7th	1304	271	590	5'54	2'79	5'94	1018	3'07	1'52	1:2'06	11'03	0'52	0'22
9963 1637 4290 56'72 18'53 40'10													

Total food nitrogen = 107'68 grms. for 13 days.
Total (urine and faeces) nitrogen = 108'69 grms. for 13 days.
Percentage of protein not absorbed = 30'8 for 13 days.

The table (Table II) shows the total daily amount of food, the amount of nitrogen therein, the amount of nitrogen excreted in urine and faeces, as also the output of urea, uric acid, chlorides, phosphates and iron.

Attention may be drawn first to the small amount of food consumed, although there was complete nutrition, the weight in fact slightly increasing during the period of experiment. The total intake of nitrogen only amounts to slightly over 8 grammes on the average for the fortnight, corresponding to about 50 grammes of proteid, and as the excretion in the faeces amounts to about 30 per cent. it is clear that still less than 50 grammes a day is utilised by the organism.

Taking fully into account the patient's weight, the deduction may safely be drawn that for a person of similar constitutional habits but of average weight, 70 grammes of proteid, and that chiefly as vegetable proteid, will suffice for the maintenance of equilibrium. The food is obviously not all vegetable in origin, there being a fair allowance of milk and butter; still a large amount of the proteid used was of vegetable origin; and the dietary shows that health and equilibrium of nutrition can be maintained not only on much less proteid than has been until recently held possible, but also that this less supply of proteid may be given in great part in vegetable forms.

The results cast a light on the metabolism of the large races of mankind which live chiefly on rice and other carbohydrate food, and show that equilibrium under such conditions and a healthy life are quite possible. Hitherto the only possible explanation, based on the minimum demand for proteid shown by Western dietaries such as those of v. Ranke and Voit, was that such races obtained proteid in some unconsidered form in amount necessary to make up to the supposed minimal quantity. Here, however, is an undoubted case, where any fraud may be ruled out, and where samples from exact duplicates of the food were carefully analysed daily, in which the amount of daily proteid does not exceed that which would be found in the daily vegetable, chiefly carbohydrate, dietary of an Eastern race.

The output of urine was excessively low. The weight of material (water) which must have left the body by the skin and lungs is about equal to that excreted as urine and faeces together. Thus, in first week, total ingesta = 9526 grammes ; faeces and urine = 4491 grammes ; therefore excretion by skin and lungs = 5035 grammes ; during second week, total ingesta = 9963 grammes ; faeces and urine = 5927, therefore excretion by skin and lungs = 4036 grammes.

Intake and Output of Iron

For the sake of completeness as well as for the interest and importance of this department of metabolism, we estimated the intake and output of iron for the last seven days.

The method employed was that recommended by Stockman,¹ great care being taken to entirely remove organic matter, before reducing with zinc to the ferrous condition.

If we accept Stockman's² statement the quantity of iron in ordinary dietaries seldom exceeds 10 milligrams per day, and may be as low as 6 milligrams in people of ordinary appetite and digestion, we must infer that the above vegetarian dietary provided an ample supply. The average amount of iron for the seven days' dietary estimated, reached 8 milligrams daily, and the average output in the faeces was 3 milligrams daily, which corresponds closely with the output in one of Stockman and Greig's subjects.

Since it is well known that practically no iron is excreted in the urine, these figures indicate that during this period a storage of iron in the organism was occurring. It is clear that at other periods this process must be reversed, and hence in the adult, as in the foetus, the liver and other haematopoietic organs must possess the power of storing and setting free iron as occasion requires. Several examinations of the subject's blood demonstrated that he was normal in haemoglobin and had a low average count of leucocytes. It is clear, therefore, from the point of view of low metabolism that the

1. *Journ. of Physiology*, Vol. XVIII, p. 484, 1895.

2. Stockman & Greig, *Ibid*, Vol. XXI, p. 55, 1879.

above apparently meagre diet contains sufficient ferruginous material for the wants of the body. The minute amounts involved tend to corroborate Bunge's theory that in anaemia the inorganic salts of iron when administered are not directly absorbed but react indirectly on some of the fermentative or digestive products present in the intestine, which would otherwise abstract iron from the body. A certain parallelism between retained iron and excreted nitrogen is observable in the Table, which possibly suggests that in the course of metabolism albuminised iron plays an important part.

The presence of gout in the family history and in that of the subject himself is interesting for two reasons :—

(1) Apparently this vegetarian régime had a beneficial effect in course of time in removing the deposits from the fingers.

(2) The recurrence of the arthritic symptoms during residence in a most salubrious locality, but close to the sea and with a hard water supply.

The latter observation suggested the comparison of the urinary inorganic bases with those of a case of acute podalgic gout, and this was done with a subject of about the same age and height who was an excessive meat eater. It may be added that the vegetarian consumed no table salt other than that in the food, while the meat-eater used large quantities.

The distribution of bases in the inorganic constituents of the urine was estimated for one period of twenty-four hours in each case.

The results are shown in the following statement :—

	Volume of urine	Na ₂ O	K ₂ O	CaO	MgO
Healthy vegetarian	250	1·520	0·543	0·039	0·139
Gouty patient	650	1·575	0·439	0·206	0·179

Stated as percentages of total base the figures become in each case :

	Na	K	Ca	Mg
Vegetarian	67·8	24·4	1·3	6·3
Gouty patient	67·5	16·8	8·4	7·1

The difference in calcium output is the most interesting fact given by the above figures, especially when it is remembered that the total amount of urine excreted by the gouty patient was more than double that of the vegetarian.

The figures suggest that perverted calcium excretion may be a factor in the pathogeny of gout, and that in gout an excess of calcium is being excreted by the kidneys, which under normal conditions would be removed by intestinal excretion.

Results which will shortly be published show that inorganic salts have a marked depressing action on the solubility of urates, and hence the vegetarian urine would be in this comparison a much more favourable vehicle than that of the gouty patient for uric acid removal.