XLIII. THE BIOLOGICAL VALUE OF BREAD-PROTEIN.

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I HAVE read with great interest the work of Martin and Robison [1922] on the biological value of various proteins for human nutrition, which I am sorry not to have seen before. Twelve years ago I carried out similar experiments [Hindhede, 1913, 1914] on several persons extending over much longer periods (309 and 126 days); but, whereas I found the protein of bread to be of full value, Martin and Robison have found a value of only 30–35 % as compared with animal protein.

How are these entirely different results to be explained? In my opinion the explanation must be sought in the fact that these investigators did not continue for any prolonged period on a sufficiently low quantity of digestible nitrogen (nitrogen in food – nitrogen in faeces). According to my experience the nitrogen minimum in urine cannot be attained in a few days. Of course on a bread diet it is no easy matter to reduce the nitrogen intake to a low level, whilst maintaining a sufficient calorie value, bread being comparatively rich in nitrogen. By chance we discovered that this was practicable by adding fruit, which accelerates the passage through the intestines, thus reducing the absorption, especially of nitrogenous compounds.

The following examples serve to illustrate this fact.

F. M.* Period III, 1913. 12 days.

	Weight g.	Dry matter g.	N g.	Calories
One day				
Rye-bread	1000	661	11.71	2817
Margarine	125	108	0.16	984
In food	1125	769	11.87	3801
In faeces	417	96	4.42	480
Absorbed	—	673	7.45	3321
In urine	—	—	7.33	—
Balance	—	—	+0.12	—
Loss, %	—	12.5	37.2	12.6

F. M. Period X, 1913. 12 days.

	Weight g.	Dry matter g.	N g.	Calories
Rye-bread	542	356	6.72	1523
Margarine	121	104	0.16	953
Prunes, dried	625	338	2.06	1383
Sugar	108	107	—	442
Starch	75	61	0.01	252
In food	1471	966	8.95	4553
In faeces	833	127	5.62	608
Absorbed	—	839	3.33	3945
In urine	—	—	3.62	—
Balance	—	—	–0.29	—
Loss, %	—	13.1	62.8	13.4

* F. M. = Frederik Madsen. H. M. = Holger Madsen.

F. M. Period XII, 1913. 8 days.

	Weight g.	Dry matter g.	N g.	Calories
One day				
Rye-bread	550	361	7.09	1549
Margarine	125	108	0.16	984
Strawberries	2500	267	3.40	1083
Sugar	275	272	—	1127
Starch	138	112	0.02	464
In food	3588	1120	10.67	5207
In faeces	875	167	6.85	797
Absorbed	—	953	3.82	4407
In urine	—	—	2.83	—
Balance	—	—	+0.99	—
Loss, %	—	15.10	64.2	15.3

It will be seen from the last period that a net intake of 3.82 g. N was sufficient not only to cover the output of nitrogen in the urine, but even to store 1 g. N per day in the body. But it may be said that probably the protein in the fruit has a high value. Is it possible that the 3.82 g. absorbed N was almost entirely derived from the protein of the strawberries (3.40 g. N) whilst practically all the bread-protein passed out with the faeces? None of the witnesses of the experiments thinks so. The enormous mass of faeces seemed to consist almost solely of strawberry seeds, and there is hardly any doubt that the N of strawberries is chiefly present in the seeds, which pass through the intestines almost unchanged. We tested the digestibility of the protein by treating it for 48 hours in the thermostat with pepsin-HCl and found that there were digested of

Protein in ryebread (unbolted)	76 %
„ prunes ...	33 %
„ strawberries ...	38 %

Forty-eight hours in the thermostat is very energetic treatment, with which the animal stomach does not seem to be able to compete.

Our previous experiments with potato diets show that there is no limit to the extent to which the digestible nitrogen of food can be reduced by this method. The following example may be given.

F. M. Period V, 1912. 8 days.

Food per day: 2354 g. potatoes, 153 g. margarine.

	Dry matter g.	N g.	Calories
In food	717	5.35	3609
In faeces	16	0.85	82
Absorbed	701	4.50	3527
Loss, %	2.2	15.9	2.3

F. M. Period X, 1912. 8 days.

Food per day: 700 g. potatoes, 75 g. margarine, 2519 g. strawberries, 162 g. starch, 375 g. sugar.

	Dry matter g.	N g.	Calories
In food	986	5.19	4391
In faeces	128	5.16	624
Absorbed	858	0.03	3767
Loss, %	13.0	99.4	14.2

This method possesses the great advantage of enriching the diet with vitamins and also with alkaline salts which neutralise the acids formed from

the oxidation of the bread-proteins, so that the body is spared the necessity of providing ammonia for this purpose. Moreover it makes the diet considerably more savoury.

The following table gives the average of the N assimilation per day during the various periods.

Period	No. of days	F. M.				H. M.			
		Absorbed N g.	N in urine g.	N-balance g.	Body-weight kg.	Absorbed N g.	N in urine g.	N-balance g.	Body-weight kg.
—	—	—	—	—	78.0	—	—	—	67.0
IV	22	4.00	4.71	-0.71	77.0	3.17	4.05	-0.88	67.5
V	12	4.76	4.89	-0.13	76.0	4.74	5.09	-0.35	66.0
VI	12	5.07	4.89	-0.22	75.5	4.99	4.66	+0.33	68.0
VII	12	4.53	5.11	-0.58	75.5	5.13	4.77	+0.36	67.5
VIII	12	3.70	4.44	-0.74	72.0	3.55	3.37	+0.18	67.0
IX	12	3.01	3.57	-0.56	73.0	5.63	4.37	+1.26	67.0
X	12	3.33	3.62	-0.29	73.0	4.84	4.53	+0.31	67.0
XI	12	3.64	3.50	+0.14	73.4	3.16	3.55	-0.39	67.0
XII	6	3.69	3.36	+0.33	73.6	4.01	2.85	+1.16	66.5
XIII	8	3.82	2.83	+0.99	74.0	3.00	3.27	-0.27	66.0
XIV	6	8.49*	5.86	+2.63	74.0	6.28	5.00	+1.28	66.0

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* In period XIV only bread is consumed. Note that here there is a great surplus of N in the food: This does not agree with Martin and Robison's experiments.

The average of the periods (bold type) in which the amounts of absorbed N were lowest is shown below:

		Per diem		
		Absorbed N	N in urine	Balance
F. M.	50 days	3.45	3.42	+0.03
H. M.	38 „	3.38	3.32	+0.06

From these experiments I conclude that 3.50 g. digestible N, equivalent to 22 g. digestible bread protein is sufficient to keep young, vigorous men in protein balance. How, then, is it to be explained that the two English experimenters could not attain balance on correspondingly low amounts.

Let us look at their figures.

The following table has been compiled from the results given by Martin and Robison, the absorbed N being taken as equal to the N intake minus the total N of the faeces.

Period	No. of days	C. J. M.				R. R.			
		Absorbed N g.	N in urine g.	N-balance g.	Body-weight kg.	Absorbed N g.	N in urine g.	N-balance g.	Body-weight kg.
1	3	3.56	5.62	-2.06	61.5	4.24	5.62	-1.38	57.7
2	3	6.46	7.62	-1.16	61.4	6.59	7.31	-0.72	58.1
3	3	6.62	7.42	-0.80	—	7.66	8.18	-0.52	—
4	3	8.24	7.46	+0.75	61.0	8.30	8.32	-0.02	57.9
5	8	7.90	8.43	-0.53	61.6	8.03	8.93	-0.90	57.4
6	4	9.47	9.23	+0.24	61.4	9.30	9.34	-0.04	57.7

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It will be seen that our experiments extend over a period five times as long as that of the English experimenters. The main difference may be

characterised as follows: when in the course of three days C. J. M. and R. R. do not succeed in obtaining balance on 3.56 or 4.24 g. digestible N, it is taken for granted that balance cannot be obtained on this level and the N in the food is then greatly increased. But as the N in the urine is increased almost proportionately, balance is not attained even by this, and so the intake is further increased. Only at 8-9 g. digestible N is balance attained with C. J. M., but with R. R. balance is not even reached by this. From this it would appear that 50-60 g. digestible bread-protein is required to attain balance, which means that the biological value of bread-protein is only about one-third that of meat-protein (body-protein).

In the Danish experiments the method is reversed. We continue for 22 days with respectively 3.17 and 4.00 g. digestible N, although the N balance is negative. From other experiments we have learned that with a very low level of N intake, the N in the urine does indeed quickly decrease until balance is nearly attained, but months may pass before the last trace of stored N disappears. At the same time we have learned that such a prolonged negative balance is of no consequence whatever as regards the state of health and the capacity for work. In this connection it may be mentioned that a negative balance continued for a prolonged period may prove an excellent cure for a number of chronic diseases¹.

F. M. loses weight during the first months (22. ii. 20. v.), but that is always the case with F. M. during the busy spring time, when, in his capacity as a skilled gardener, he does 6 to 7 hours' hard garden work a day, besides his 7 hours' work at the laboratory. The testimony of one of his employers provides abundant evidence of Madsen's extraordinary vitality and his capacity for long continued labour of the heaviest description whilst on this diet.

During the last 50 days, when the N in his food is most reduced, he does not lose weight, but on the contrary, gains a little. With H. M., the other subject of experiment, the weight remains almost constant. It may be added that he competed in a long-distance walking match and covered 264 miles in 99.35 hours (74.33 hours for walking, 25.02 for rest and sleep), finishing fourth out of nine competitors.

The only way to reduce the N secretion in urine is by a strong reduction of the N intake. Balance is, curiously enough, not infrequently most easily obtained by reducing the N in the food very far—to a certain limit, of course. Only then is the removal effected of the last remnant of stored N which tends to disturb the results.

The English authors use complicated formulae in the calculation of the biological value of the various proteins; but even the most elaborate formulae are to no purpose if the figures put into them are not correct. I find no occasion to go into these formulae. I content myself by concluding that when two young, vigorous men can maintain balance on 22 g. digestible bread-

¹ Cf. Dr Sandoz [1907, p. 219]. "Plus l'histolyse sera intense, plus la transformation qui doit conduire à la guérison sera rapide et complète."

protein, the bread-protein must have essentially the same value as protein in meat and milk. I do not, therefore, consider it correct that the biological value of protein in whole wheat is only 31–35 %. And this scepticism as to the method seems to me to be supported by the fact that, by the same method, Prof. Martin and Dr Robison found that milk-protein has a biological value of only 51 %. Here they are also at variance with the results of other investigators.

Of course there is the difference that Martin and Robison used wheat-bread, whilst we used rye-bread, but according to our other experiments with wheat and rye it seems to me impossible to believe that wheat-protein should be so inferior to rye-protein.

Not till Prof. Martin and Dr Robison have, for a couple of months, tried a diet containing only about 3.50 g. digestible bread-N besides sufficient calories, vitamins and salts—not till then have they furnished any proof of the small value of bread-protein.

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