VOLUME XII JUNE, 1912 No. 2

SOME EXPERIMENTS ON THE RELATIVE DIGESTIBILITY OF WHITE AND WHOLEMEAL BREADS.

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THE problem of the comparative nutritive value of bread made from the various high grade white or "patents" flours and the so-called "standard" meal is of some interest. The inclusion of a considerable portion of the bran in standard bread is claimed to increase largely the nutritive value of the bread. It has been known for many years that wholemeal bread containing the bran particles was especially useful as an article of diet for persons suffering from constipation, the laxative effect being due partly to the mechanical presence of indigestible fibre, partly to the irritation of the intestinal wall by the sharp bran particles causing increased peristalsis. This effect is to some extent lost after prolonged feeding.

Of late years the producers of standard bread flours have laid considerable stress on the greater nutritive value of bread made from these flours and it was to test these asseverations that the feeding trials recorded in this paper were made. Four men took part in the actual feeding, as follows:

TABLE I.

	I	II	III	IV
	H. A. D. N. Aet. 31	L. F. N. Aet. 29	J. H. Aet. 24	E. T. H. Aet. 23
Height	5 ft. 5 ins.	5 ft. 9 ins.	6 ft. 3 ins.	5 ft. 6 ins.
Weight	9 st. 6½ lbs.	12 st. 12 lbs.	12 st. 8¼ lbs.	9 st. 9½ lbs.
Profession	Research chemist	Chemist	Research physiologist	Research physiologist

[1] The experiments were carried out in the School of Agriculture at Cambridge, under the supervision of Prof. T. B. Wood and Dr F. Gowland Hopkins.

A considerable number of feeding experiments have been carried out in the United States by chemists at the various experimental stations but in nearly all cases two-day periods only were taken, and it is certain that owing to the difficulty of accurately demarcating the faeces this period is much too short. Ingestion of a charcoal biscuit is the usual way and it is impossible accurately to separate the faeces of the first day of the experiment from those of the preceding period. The sacculations of the colon hold up part of the excreta and so prevent a clear separation of the faeces resulting from any one meal. In fact in the following experiments tomato pips and skin were identified in the faeces three days after the charcoal-coloured stool had been passed. To reduce this error as far as possible and to allow a fair period to cover small differences in metabolism, the experiment was divided into two periods of a week each. Bread made from high grade white or "patents" flour being taken for the first part and a "wholemeal" bread made from flour from which only about 20 % of bran had been removed for the second.

The daily ration consisted of 750–800 grams of bread, 600 c.c. of milk, 30 grams of butter-fat, filtered so as to be free from casein and water, and 20 grams of sugar. The food was taken in four meals, 8 a.m., 1 p.m., 4.30 p.m. and 7.30 p.m. The food was apportioned into two lots, for the morning and evening meals of each day.

The bread was baked into loaves of such a size that two of them furnished the requisite amount per day. A slice was cut out of each loaf for the purpose of analysis and the remainder weighed for the ration. Each slice was weighed on a numbered aluminium tray and dried to constant weight at about 50° C. From the weight after drying, the percentage of air-dry bread in each man's ration was calculated. The air-dry samples for each pair of meals were united, ground up and bottled, so that two air-dry ground samples were obtained for each day, one for the morning and the other for the evening meal. On these air-dried samples the analyses were made.

The milk was delivered once each day about 3.30 p.m., and 300 c.c. were measured out for each man for the evening meals of that day, and for their portions of 300 c.c. for the morning meals of the following day. Before measuring out any milk, about 350 c.c. were taken out as a sample and preserved with 2 c.c. of formalin.

With regard to the collection of the excreta, the experiment commenced at 8 a.m. Nov. 7. The bladder was completely emptied at that hour and all urine passed after that and until 8 a.m. on the following morning was collected as the urine for the day, and made up to 2000 c.c., 2·3 c.c. of chloroform being used as a preservative.

In the case of the faeces, a carbon biscuit was taken after the last meal before the experiment. All stools after the beginning of the experiment were examined for the appearance of the carbon, and by this means it was possible to determine which faeces belonged to the experiment. The end of the experiment was similarly marked. Stools were passed into counterpoised dishes and after spraying with dilute sulphuric acid to fix any ammonia, were set to dry in an air oven at about 100° C. The drying was facilitated by mixing a little alcohol with the faeces from time to time. The dishes were later placed in a steam oven and dried to constant weight. As it was not easy to apportion the faeces out accurately to the days of the experiment in the same way as the urine, the faeces for each man for the whole period were united and ground as one sample.

Each man was weighed before the second meal of each day and the weights are shown in a table (Table II). There was a slight falling off of weight except in the case of Individual I.

TABLE II.

Daily weights of subjects in kilos.

	Nov. 7	Nov. 8	Nov. 9	Nov. 10	Nov. 11	Nov. 12	Nov. 13
I	60·2	60·3	60·4	60·2	60·0	60·4	60·8
II	81·7	81·4	81·8	81·0	80·9	81·3	81·4
III	80·0	79·8	79·5	78·3	78·7	78·4	78·9
IV	61·5	61·2	60·7	60·2	60·4	60·5	60·4
	Nov. 30	Dec. 1	Dec. 2	Dec. 3	Dec. 4	Dec. 5	Dec. 6
I	60·3	60·6	61·1	61·1	60·8	60·9	60·1
II	81·7	81·6	82·1	81·6	81·5	81·4	80·9
III	80·1	79·9	80·2	79·5	79·8	79·8	78·8
IV	63·2	62·4	63·1	62·3	63·2	62·3	62·2

	Jan. 24	Jan. 25	Jan. 26
II	83·2	82·7	82·4
IV	62·2	62·8	62·2
	Jan. 27	Jan. 28	Jan. 29
II	81·9	81·4	81·7
IV	62·2	61·7	62·2
	Jan. 30	Jan. 31	Feb. 1
II	81·9	81·7	81·3
IV	61·7	61·4	61·2

The experiment caused little derangement in the health and well being of the subjects except that III was slightly indisposed on the second and third days of the first period.

The following figures show the intake of each individual per kilo of body-weight for the first two periods:

Individual	Calories per kilo		Nitrogen per kilo	
	Period 1 white bread	Period 2 brown bread	Period 1 white bread	Period 2 brown bread
I	52·05	54·20	0·203	0·193
II	39·50	42·30	0·154	0·153
III	42·10	44·90	0·165	0·163
IV	51·20	52·30	0·200	0·180

Estimations were made on the food and the excreta to determine

1. The amount of energy in each item of the daily ration, and hence the total energy taken in by each man on each day of the experiment.

2. The amount of nitrogen in the bread and milk, by which the total amount of nitrogen consumed by each man on each day of the experiment was found.

3. The amount of P_2O_5 in the same way as the nitrogen.

4. Energy, nitrogen and P_2O_5 in the urine and faeces.

Assuming that the whole of the butter-fat, sugar and milk were digested the availability of the bread constituents could then be calculated from the data obtained.

Both the standard and white bread parts of the experiment were carried out on exactly the same lines. An interval of three weeks was allowed between the two periods.

After the two week experiment was finished it was thought advisable to repeat the wholemeal diet period with flours containing varying percentages of bran and also to include a period with some inorganic phosphate added to the ration. As these results were of comparatively small importance it was considered sufficient for the purpose for two only of the individuals to undergo the dietary, to reduce the periods to three days each and to collect each period's milk, bread and urine samples in one lot for each individual as well as the faeces. Throughout this series the same amounts of milk, butter-fat and sugar were taken as in the previous periods and the collection of excreta and the methods of analysis were kept uniform with the former experiments.

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The dietary period was divided into three parts. For the first a standard flour with only 8 % of the bran removed was used. During the second and third parts a somewhat finer meal was used from which about 12 % of bran had been removed. During the third part 3 grams of freshly prepared bone ash containing 1·28 gram P_2O_5 was added to the daily ration; this increased the inorganic phosphates in the diet by 3·84 grams.

Energy metabolism.

The determinations of the calorific values of the food substances, faeces and urine, in this investigation, were carried out in a Berthelot bomb calorimeter of the type usually employed for the accurate determination of heats of combustion, and, after due correction for radiation errors, duplicate determinations were found to agree within narrow limits.

The preparation of materials is briefly described below:

Bread. The dried material prepared as described (p. 120) was used, about 1 gram of a representative finely ground sample being pressed into tabloid form.

Butter. From each lot of butter purchased a portion was set aside, melted, and filtered free from water and curd. From the mixed sample so obtained about 0·5 gram was taken for combustion.

Milk. The milk solids were obtained from a sample made up of 100 c.c. of milk from each day's delivery. The liquid was evaporated on a water-bath until sufficient water had been removed to give an easily manipulated solid.

Sugar. No actual determinations were made, the standard figure for cane sugar being taken.

Faeces. The dried material prepared as described (p. 121) was used, about 1 gram of the material being found a suitable quantity.

Urine. The urine of each individual was daily made up to 2000 c.c. with water, and a 100 c.c. sample of the liquid so obtained, with a few drops of chloroform added, was put aside. The combined samples of each individual's urine were at the end of each period evaporated at a temperature of about 60° C., the drying being finished off in a vacuum desiccator. The later stages of the drying are rather slow and tiresome and the solids, owing to their hygroscopic nature, needed careful manipulation. About 2·5 grams are required for combustion, and with care duplicate determinations agreed very well.

From the materials prepared by the methods just described the calorific values in the following tables were obtained, and along with these values are given weights of dry matter, etc. necessary for the calculation of the complete intake of energy in the food and loss of energy in the faeces and urine.

TABLE III. *Breads, calorific values.*

Period	1st day Morning meals	1st day Evening meals	2nd day Evening meals	3rd day Evening meals	4th day Evening meals	5th day Evening meals	6th day Evening meals	7th day Evening meals	Mean values
I	4035	3920	4117	4085	4083	4071	4024	3980	4039
II	4120	4111	4162	4296	4139	4149	4139	4075	4149
III	4034	4034	4034	—	—	—	—	—	4034
IV	4218	4218	4218	—	—	—	—	—	4218

Remarks:—(*a*) Figures are small calories per gram.

(*b*) The figures given for Periods III and IV are for a sample from the mixed breads from the three days.

It may be pointed out that one delivery of bread served for the last two meals of one day and the first two of the next, making eight determinations necessary for a seven day period.

TABLE IV. *Breads, dry matter eaten in grams.*

	Period I Individual				Period II Individual				Period III Individual		Period IV Individual	
	I	II	III	IV	I	II	III	IV	II	IV	II	IV
First day:	477·2	562·2	566·0	490·1	483·1	521·0	564·0	484·1	496·2	477·9	444·7	428·6
Second day:	494·1	542·3	543·4	499·5	471·5	637·6	528·8	492·1	481·5	470·1	449·7	426·5
Third day:	492·9	530·5	585·1	516·0	515·3	567·4	634·8	515·9	478·6	462·9	458·5	446·0
Fourth day:	537·0	512·0	522·0	526·0	492·6	537·8	571·3	442·8	—	—	—	—
Fifth day:	495·0	497·0	600·0	502·0	502·3	504·5	585·9	493·0	—	—	—	—
Sixth day:	455·5	502·0	565·0	455·5	471·6	536·4	561·9	484·3	—	—	—	—
Seventh day:	492·0	472·0	471·5	492·0	503·1	488·0	567·5	459·8	—	—	—	—

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TABLE V. *Weights eaten and calorific values of other foodstuffs used.*

	Butter		Milk			Sugar	
Period	Weight taken daily	Small calories per gram	Volume taken per day	Grs. solids per 100 c.c.	Calorific value per gr. solids	Weight taken per day	Calorific value per gram
I	60 grs.	9337	600 c.c.	17·03	4937	20 grs.	3960
II	60	9330	600	16·13	5972	20	3960
III	60	9311	600	15·06	5869	20	3960
IV	60	9311	600	15·07	5702	20	3960

Remarks:—(*a*) The milk solids were not water-free. Desiccation was only carried far enough to give a solid which could be manipulated.

(*b*) The standard figure for cane sugar is given and no determinations were carried out.

TABLE VI. *Faeces.*

	Period I		Period II		Period III		Period IV	
Individual	Wt. per day, dry matter	Calorific value per gram	Wt. per day, dry matter	Calorific value per gram	Wt. per day, dry matter	Calorific value per gram	Wt. per day, dry matter	Calorific value per gram
I	13·1	5239	31·2	4778	—	—	—	—
II	16·9	5452	31·6	4908	62·6	4865	49·8	4805
III	20·9	5240	26·7	4813	—	—	—	—
IV	14·8	5618	26·0	4986	48·2	4821	49·7	4762
Mean	16·4	5387	28·9	4870	55·4	4843	49·75	4783

Remarks:—In four cases the figure given is the mean of duplicate determinations which agreed well.

TABLE VII. *Urine.*

	Period I		Period II		Period III		Period IV	
Individual	Wt. per day, solid matter	Calorific value per gram	Wt. per day, solid matter	Calorific value per gram	Wt. per day, solid matter	Calorific value per gram	Wt. per day, solid matter	Calorific value per gram
I	27·42	1848	38·80	1770	—	—	—	—
II	22·70	1478	36·90	1509	56·35	1923	40·31	1890
III	48·84	2120·5	33·40	1435	—	—	—	—
IV	29·82	1678	36·40	1203	52·71	1794	47·24	1923

Remarks:—As evaporation of the urine was only carried on till a solid which could be manipulated was obtained, the "solid matter" referred to in the Table was in no case free from water and different samples probably contained varying amounts of water.

From the above tables the percentage utilisation of the energy of the food can easily be calculated and the results are set out in tabular form below.

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TABLE VIII. *Period I. Energy Utilisation Table.*

Energy content of food and excreta		Individual			
		I	II	III	IV
Bread ...	...	13927	14624	15586	14080
Butter ...	...	3920	3920	3920	3920
Milk ...	...	3535	3535	3535	3535
Sugar ...	...	553	553	553	553
Total energy content of food		21935	22632	23594	22088
Faeces ...	...	480	643	767	582
Urine ...	...	266	176	495	263
Total energy loss in excreta		746	819	1262	845
Percentage loss in	Faeces	2·18 %	2·84 %	3·25 %	2·63 %
	Urine	1·21 %	·78 %	2·09 %	1·19 %
Percentage Utilisation ...		96·61 %	96·38 %	94·66 %	96·18 %

Remarks :—(*a*) Calorific values in thousands of calories.

(*b*) As it is desired to calculate the utilisation of the bread, a certain portion of the total energy of the urine must be subtracted to allow for the urine solids due to the nitrogen in the milk. This has been done in the figures given in this Table, one-fourth being so subtracted as the nitrogen in the milk was approximately one-fourth of the total nitrogen of the diet.

(*c*) The low utilisation in the case of Individual III was probably due to this subject being indisposed during two days of the experiment.

TABLE IX. *Period II. Energy Utilisation Table.*

Energy content of food and excreta		Individual			
		I	II	III	IV
Bread ...	...	14335	15740	16689	14018
Butter ...	...	3919	3919	3919	3919
Milk ...	...	4045	4045	4045	4045
Sugar ...	...	553	553	553	553
Total energy content of food		22852	24257	25206	22535
Faeces ...	...	1043	1085	899	908
Urine ...	...	481	293	252	230
Total energy loss in excreta		1524	1378	1151	1138
Percentage loss in	Faeces	4·56 %	4·47 %	3·57 %	4·03 %
	Urine	1·58 %	1·20 %	·99 %	1·02 %
Percentage Utilisation ...		93·86 %	94·33 %	95·44 %	94·95 %

Remarks :—(*a*) Calorific values in thousands of calories.

(*b*) See note (*b*), Table VIII.

(*c*) Individual III, who was in good health throughout this part of the experiment, here gives a more normal utilisation figure thus confirming the idea that the low figure for this subject in the previous period was due to indisposition.

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TABLE X. *Periods III and IV. Energy Utilisation Table.*

Energy content of food and excreta		Period III Individual II	Period III Individual IV	Period IV Individual II	Period IV Individual IV
Bread ...	...	5875	5692	5707	5488
Butter ...	...	1676	1676	1676	1676
Milk ...	...	1591	1591	1547	1547
Sugar ...	...	238	238	238	238
Total energy content of food		9380	9197	9168	8949
Faeces ...	...	907	697	718	710
Urine ...	...	244	213	171	204
Total energy loss in excreta		1151	910	889	914
Percentage loss in	Faeces	9·67 %	7·58 %	7·83 %	7·93 %
	Urine	2·60 %	2·31 %	1·86 %	2·28 %
Percentage Utilisation ...		87·73 %	90·11 %	90·31 %	89·79 %

Remarks:—(*a*) Calorific values in thousands of calories.
(*b*) See note (*b*), Table VIII.

Taking the utilisation figures from the three preceding tables and working out the average utilisation in each period we get

	Period I	Period II	Period III	Period IV
Utilisation	95·96 %	94·64 %	88·92 %	90·05 %

Of the "standard" breads therefore the best showed an utilisation efficiency 1·32 % lower than the white bread, while, as the bran content of the flour increases, as in Periods III and IV, the utilisation efficiency diminishes, so that when a 92 % meal is used it falls to 88·92 % or 7·04 % below the white bread.

When the utilisation percentage is considered in conjunction with the energy content, the calories utilised by the subject per gram of dry matter came out as follows:—

	Period I	Period II	Period III	Period IV
Calories per gr. dry matter	3875	3926	3587	3798

The sample of "standard" bread used in Period II appears to have higher value than white bread, but the difference is hardly outside the limits of experimental error. The other samples of "standard" bread are however still below the white bread in energy value.

If the percentage of water in the samples of bread used be also taken into consideration the calorific value per gram of bread, as used, becomes

	Period I	Period II	Period III	Period IV
Calories per gram	2666	2811	2263	2354

Generally speaking there was little or no difference between the sample of "standard" bread used in Period II and the white bread used in Period I, but the much coarser brown breads used in Periods III and IV, with higher bran contents, fall appreciably below both the white bread and the finer "standard" bread.

A minor point brought out by the investigation was the great irregularity of the energy content of both urine and faeces per gram of nitrogen. Thus in Period I we get

Small calories per gram of nitrogen in the urine.

Individual—I	II	III	IV
4758	2447	6998	3980

while in Period II the figures are

Individual—I	II	III	IV
6719	4859	3338	3821

In the faeces the energy per gram of nitrogen is as follows

	Individual—I	II	III	IV
Period I.	86874	92138	82343	85718
Period II.	110425	109131	101989	112727

It will be noticed that there is a 300 % variation for different individuals in the urine while the variation is considerable in the faeces.

Nitrogen.

For the estimation of the nitrogen, 10 c.c. milk, 5 c.c. urine, and about 1·3 grams bread or faeces (dry matter) were taken. The filtered butter-fat was assumed to be nitrogen free. Kjeldahl's method was used, duplicate estimations being done in all cases.

By this method the percentage of nitrogen in the milk and in the dry matters of the bread and faeces was obtained, together with the total nitrogen excreted per individual per day in the urine. From these data the total intake and output of nitrogen per individual per day were calculated. The faeces were collected over the whole period and averaged, the total loss of nitrogen per day by way of the faeces thus being obtained. Thus, by subtracting the faecal nitrogen from the nitrogen intake the nitrogen absorbed and digested by the individual was obtained. Assuming total digestion of the nitrogen of the milk, the digestibility of the nitrogen of the bread under consideration was calculated. No allowance was made for what Lusk calls "normal faeces," *i.e.* faeces excreted by the digestive tract itself (breakdown bile pigments, mucus etc.).

The results obtained are expressed in the following tables:—

TABLE XI. *White Bread.*

Nitrogen in grms. in	Nov. 7	Nov. 8	Nov. 9	Nov. 10	Nov. 11	Nov. 12	Nov. 13	Total
Individual I.								
Bread	8·87	9·27	8·97	9·90	9·18	8·44	9·13	63·76
Milk	3·18	3·15	3·09	3·09	3·06	3·06	3·06	21·69
Faeces	·79	·79	·79	·79	·79	·79	·79	5·53
Urine	10·14	10·75	10·19	11·09	11·26	10·53	10·58	74·54
Individual II.								
Bread	10·13	10·20	9·66	9·44	9·21	9·28	8·76	66·68
Milk	3·18	3·15	3·09	3·09	3·06	3·06	3·06	21·69
Faeces	1·00	1·00	1·00	1·00	1·00	1·00	1·00	7·00
Urine	13·75	14·42	13·30	14·45	14·28	13·27	12·60	96·07
Individual III.								
Bread	10·51	10·18	10·67	9·62	11·07	10·46	8·76	71·27
Milk	3·18	3·15	3·09	3·09	3·06	3·06	3·06	21·69
Faeces	1·33	1·33	1·33	1·33	1·33	1·33	1·33	9·31
Urine	15·57	14·84	15·40	13·66	13·33	13·16	12·71	98·67
Individual IV.								
Bread	9·12	9·37	9·40	9·70	9·29	8·45	9·16	64·49
Milk	3·18	3·15	3·09	3·09	3·06	3·06	3·06	21·69
Faeces	·97	·97	·97	·97	·97	·97	·97	6·79
Urine	12·15	13·08	13·66	12·54	13·05	12·32	11·87	88·67

TABLE XII. *"Standard" Bread.*

Nitrogen in grms. in	Nov. 30	Dec. 1	Dec. 2	Dec. 3	Dec. 4	Dec. 5	Dec. 6	Total
Individual I.								
Bread	8·57	8·60	9·06	8·45	8·85	8·30	8·82	60·65
Milk	3·00	2·95	2·93	2·97	2·96	2·94	2·94	20·69
Faeces	1·35	1·35	1·35	1·35	1·35	1·35	1·35	9·45
Urine	11·26	9·18	10·42	10·25	10·58	10·30	9·52	71·51
Individual II.								
Bread	9·24	11·38	10·14	9·22	8·89	9·43	8·55	66·85
Milk	3·00	2·95	2·93	2·97	2·96	2·94	2·97	21·72
Faeces	1·42	1·42	1·42	1·42	1·42	1·42	1·42	9·94
Urine	11·48	11·20	12·21	11·14	11·14	11·65	11·42	80·24
Individual III.								
Bread	10·01	9·43	11·19	9·80	10·31	9·88	9·97	70·59
Milk	3·00	2·95	2·93	2·97	2·96	2·94	2·94	20·69
Faeces	1·26	1·26	1·26	1·26	1·26	1·26	1·26	8·82
Urine	16·57	14·67	14·67	12·94	14·78	13·50	13·38	100·51
Individual IV.								
Bread	8·59	8·79	9·06	7·60	8·70	8·52	8·07	59·33
Milk	3·00	2·95	2·93	2·97	2·96	2·94	2·94	20·69
Faeces	1·15	1·15	1·15	1·15	1·15	1·15	1·15	8·05
Urine	12·10	12·37	12·04	11·20	11·14	11·42	9·97	80·24

https://doi.org/10.1017/S0022172400017095 Published online by Cambridge University Press

It will be seen that roughly three-fourths of the nitrogen taken in (in the form of protein) by the individual was supplied by the bread. Reference to the tables of weights of individuals shows that the daily loss of nitrogen by way of faeces varies directly with the weight of the individual.

TABLE XIII. *White Bread.*

Nitrogen in grms. in	Nov. 7	Nov. 8	Nov. 9	Nov. 10	Nov. 11	Nov. 12	Nov. 13	Total
				Individual I.				
Intake	12·05	12·42	12·06	12·99	12·24	11·50	12·19	85·45
Output	10·93	11·54	10·98	11·88	12·05	11·32	11·37	80·07
Balance	+1·12	+0·88	+1·08	+1·11	+0·19	+0·18	+0·82	+5·38
				Individual II.				
Intake	13·31	13·35	12·75	12·53	12·27	12·34	11·82	88·37
Output	14·75	15·42	14·30	15·45	15·28	14·27	13 60	103·07
Balance	–1·44	–2·07	–1·55	–2·92	–3·01	–1·93	–1·78	–14·70
				Individual III.				
Intake	13·69	13·33	13·76	12·71	14·13	13·52	11·82	92·96
Output	16·90	16·17	16·73	14·99	14·66	14·49	14·04	107·98
Balance	–3·21	–2·84	–2·97	–2·28	–0·53	–0·97	–2·22	–15·02
				Individual IV.				
Intake	12·30	12·52	12·49	12·79	12·35	11·51	12·22	86·18
Output	13·12	14·05	14·63	13·51	14·02	13·29	12·84	95·46
Balance	–0·82	–1·53	–2·14	–·72	–1·67	–1·78	–0·62	–9·28

TABLE XIV. *"Standard" Bread.*

Nitrogen in grms. in	Nov. 30	Dec. 1	Dec. 2	Dec. 3	Dec. 4	Dec. 5	Dec. 6	Total
				Individual I.				
Intake	11·57	11·55	11·99	11·42	11·81	11·24	11·76	81·34
Output	12·61	10·53	11·77	11·60	11·93	11·65	10·87	80·96
Balance	–1·04	+1·02	+0·22	–0·18	–0·12	–0·41	+0·89	+0·38
				Individual II.				
Intake	12·24	14·33	13·07	12·19	11·85	12·37	11·52	87·57
Output	12·90	12·62	13·63	12·56	12·56	13·07	12·84	90·18
Balance	–0·66	+1·71	–0·56	–0·37	–0·71	–0·70	–1·32	–2·61
				Individual III.				
Intake	13·01	12·38	14·12	12·77	13·27	12·82	12·91	91·28
Output	17·83	15·93	15·93	14·20	16·04	14·76	14·64	109·33
Balance	–4·82	–3·55	–1·81	–1·43	–2·77	–1·94	–1·73	–18·05
				Individual IV.				
Intake	11·59	11·74	11·99	10·57	11·36	11·46	11·01	79·72
Output	13·25	13·52	13·19	12·35	12·29	12·57	11·12	88·29
Balance	–1·66	–1·78	–1·20	–1·78	–0·93	–1·11	–0·11	–8·57

The above two tables XIII and XIV give the daily nitrogen balance of the four individuals throughout the period of experiment. The period taken, a week in each case, was much too short to give any very accurate information with regard to the nitrogen balance, and consideration of the above tables shows this to be so. It is interesting to note that the nitrogen balance of Individual I was positive except for three days in the second period.

Comparing the nitrogen balances of the two periods, it will be seen that, compared with the intake of N in bread, the nitrogen balances of Individuals II and IV argued in favour of the "standard" bread, Individual II strongly so.

Individual II:

	White bread	"Standard" bread
Intake	88·37 grms.	87·57 grms.
Nitrogen balance	−14·7 ,,	−2·61 ,,

Individual IV:

	White bread	"Standard" bread
Intake	86·18 grms.	79·72 grms.
Nitrogen balance	−9·28 ,,	−8·57 ,,

The nitrogen balances of Individuals I and III reversed the decision in favour of white bread. Thus the intake of Individuals I and III was as follows:—

Individual I:

	White bread	"Standard" bread
Intake	85·45 grms.	81·34 grms.
Nitrogen balance	+5·38 ,,	+0·38 ,,

Individual III:

	White bread	"Standard" bread
Intake	92·96 grms.	91·28 grms.
Nitrogen balance	−15·02 ,,	−18·05 ,,

a decided balance in favour of white bread.

Summing up, we can say that the nitrogen balances argued slightly in favour of white bread, but that owing to the shortness of the period, and the closeness of the results, not much importance can be attached to this result.

Leaving aside the discussion as to the nitrogen balance, we come to the important consideration of the comparative digestibility of the two breads with reference to the nitrogen. The results as to the comparative digestibility of the two breads are appended in the following two tables:—

TABLE XV. *White Bread. Digestibility of White Bread.*

Individual	Bread (grms. dry)	Nitrogen, total	Nitrogen, bread	Nitrogen, faeces	Nitrogen absorbed	Percent. digested	% digested, assuming 100 % N. of milk digested
I	3443·7	85·45	63·76	5·53	79·92	93·5	91·3
II	3618·0	88·37	66·68	7·00	81·37	92·0	89·5
III	3853·0	92·96	71·27	9·31	83·65	89·9	86·9
IV	3481·0	86·18	64·49	6·79	79·39	92·1	89·5
Average	3598·9	88·24	64·55	7·16	81·08	91·9	89·3

TABLE XVI. *Wholemeal Bread. Digestibility of "Standard" Bread.*

Individual	Bread (grms. dry)	Nitrogen, total	Nitrogen, bread	Nitrogen, faeces	Nitrogen absorbed	Percent. digested	% digested, assuming 100 % N. of milk digested
I	3449·5	81·34	60·65	9·45	71·89	88·3	84·4
II	3786·8	87·57	66·85	9·94	77·63	88·6	85·1
III	4014·2	91·28	70·59	8·82	82·46	90·3	87·5
IV	3372·0	79·72	59·33	8·05	71·67	89·9	86·4
Average	3655·6	84·97	64·35	9·06	75·91	89·3	85·9

Here the results obtained are much more definite and clear. Individuals I, II and IV all digested much more nitrogen in the case of the white bread, Individual III here proving an exception in favour of wholemeal bread. On the mixed dietary, the average digestion of the individual was 2·6 % better in the case of the white bread, and, assuming that the nitrogen of the milk was entirely digested, the average digestion of the individual was 3·4 % better in the case of the white bread. We are therefore justified in concluding from this that the nitrogen (in the form of protein) of the white bread is digested to a greater extent than is the nitrogen of the "standard" bread.

Since the above results were obtained, the individual who presented the flour informed us that from the "standard" flour supplied 20 % of bran had been removed, and two more flours, in the first case containing 92 % of the meal, in the second case containing about 88 % of the meal, were supplied. The second flour was known as S 2. A further feeding experiment was conducted for nine days with these two flours, the experiment lasting three days on the 92 % meal flour, and six days on the S 2 flour, 9 grams of bone ash also being added in the last three days. Working on the same lines as before, the following results were obtained:—

https://doi.org/10.1017/S0022172400017095 Published online by Cambridge University Press

TABLE XVII. *Coarse Brown* (92 % *meal*).

N. in grms. in	92 % meal	88 % meal	88 % meal+Bone Ash
	Individual II.		
Bread	30·87	31·12	26·85
Milk	8·62	8·90	9·34
Faeces	8·39	6·54	6·49
Urine	38·09	36·10	35·41
	Individual IV.		
Bread	29·91	29·92	26·82
Milk	8·62	8·90	9·34
Faeces	5·76	5·41	4·17
Urine	35·35	34·15	31·42

TABLE XVIII.

N. in grms. in	92 % meal	88 % meal	88 % meal +Bone Ash
	Individual II.		
Intake	39·49	40·02	36·19
Output	46·48	42·64	41·90
Balance	– 6·99	– 2·62	– 5·71
	Individual IV.		
Intake	38·53	38·82	36·16
Output	41·11	39·56	35·59
Balance	– 2·58	– 0·74	+ 0·57

There is little to remark in these tables, except that Individual IV showed a plus balance of nitrogen for the last three days of the experiment. From these tables we obtain the following results:—

TABLE XIX.

(1) *Digestibility of Coarse Brown* (92 % *meal*).

Individual	Bread (grms. dry)	Nitrogen, total	Nitrogen, bread	Nitrogen, faeces	Nitrogen absorbed	Percent. digested	% digested, assuming 100 % N. of milk digested
II	1456·3	39·49	30·87	8·39	31·10	78·7	72·8
IV	1410·9	38·53	29·91	5·76	32·77	85·0	80·7
Average	1438·6	39·01	30·39	7·07	31·94	81·8	76·7

(2) *Digestibility of Brown* (88 % *meal*).

Individual	Bread (grms. dry)	Nitrogen, total	Nitrogen, bread	Nitrogen, faeces	Nitrogen absorbed	Percent. digested	% digested, assuming 100 % N. of milk digested
II	1352·9	40·02	31·12	6·54	33·48	83·6	78·9
IV	1301·1	38·82	29·92	5·41	33·41	86·3	81·9
Average	1327·0	39·42	30·52	5·97	33·45	84·9	80·4

(3) *Digestibility of Brown* (88 % *meal* + 9 *grms. Bone Ash*).

Individual	Bread (grms. dry)	Nitrogen, total	Nitrogen, bread	Nitrogen, faeces	Nitrogen absorbed	Percent. digested	% digested, assuming 100 % N. of milk digested
II	1399·2	36·19	26·85	6·49	29·70	82·0	75·8
IV	1397·5	36·16	26·82	4·17	31·99	88·4	84·4
Average	1398·3	36·17	26·83	5·33	30·84	85·2	80·1

From the above table we see that there has been a considerable drop in the digestibility, the digestibility of the nitrogen in the 92 % meal and the 88 % meal being 76·7 % and 80·4 % as compared with the 85·9 % obtained in the case of the wholemeal bread.

This table, in conjunction with Tables XV and XVI, clearly illustrates the depression of the digestibility owing to the introduction of what is technically regarded as fibre, *i.e.* indigestible residue. Thus we find that as more and more of the entire berry is included in the manufacture of the flour the less the nitrogen is digested. Putting the flours in order of % of meal we find the percentages digested to be 89·3, 85·9, 80·4 and 76·7, a clear illustration of this fact. Comparison with tables (2) and (3) of Table XIX shows also that the digestibility of the nitrogen is practically unaffected by the ingestion of comparatively large quantities of phosphorus. Thus the average percentage digestibility of the 88 % bread dropped from 80·4 to 80·1 %, a negligible amount, considering the large amount of phosphorus ingested.

It has been shown already that the digestibility of the nitrogen of the white bread is much better than the digestibility of the nitrogen of the wholemeal bread. From the consumer's point of view, however, the question that arises is not whether the nitrogen of the white bread is more easily digested than the nitrogen of the wholemeal bread, or *vice versa*, but whether, in equal quantities of bread ingested, he gets more nitrogen digested in the one case than in the other. The following table was therefore prepared, in which the actual amount of nitrogen digested in 100 grams of the breads obtained from the different flours supplied is given, the percentage N digested in the dry matter of the bread being deceptive, owing to the varying quantities of moisture contained in the various breads. These results are tabulated as follows:—

TABLE XX.

	Percentage moisture	Percentage N in bread	N in grms. digested per 100 grms. bread
White Bread	31·2	1·27	1·13
"Standard" Bread	28·4	1·26	1·08
92 % Bread	36·6	1·34	1·03
88 % Bread	37·0	1·45	1·16

From the above results it is evident that, of the flours supplied, the bread baked from the 88 % meal is the best with regard to the nitrogen actually absorbed by the individual. The differences in all four cases are of course very small, but writing the breads in order of value to the consumer with regard to nitrogen supply we should write 88 % bread, white bread, "standard" bread, and coarse brown bread (92 % meal). It should be noted that the coarser flours 88 % and coarse brown (92 % meal) contains much more nitrogen. This suggests that the method of preparation of the flours known as high grade "patents" (white) and "standard" flours, excludes more of the protein of the berry than has hitherto been suspected, especially with regard to the "'standard' flour."

Briefly summarising the results obtained we find

1. That the percentage digestibility of the protein contained in the bread decreases as the quantity of "fibre" present increases. In other words, the protein of white bread is more easily digested than the protein of "standard" bread or of breads made from coarser flours.

2. That the actual amount of protein digested from equal weights of bread depends more on the amount of moisture retained in baking and the method of preparation of the flour, than upon the percentage digestibility of the protein of the bread. This is clearly shown in the case of white bread and bread made from 88 % meal. In other words, the variation in water content is often sufficient to mask the variation in protein content of the dry matter even when allowance is made for its varying availability.

PHOSPHORUS.

Estimation of the phosphorus.

The phosphorus was estimated in the food and excreta by a modification of Neumann's method. In the case of the urine 2 c.c. of sulphuric acid were added to 10 c.c. of the urine and the mixture heated in a Kjeldahl flask until frothing ceased. 8 c.c. sulphuric acid, 4–5 grams of potassium sulphate and a crystal of copper sulphate were then added and the contents heated until all the organic matter was oxidized as evidenced by the liquid in the flask having only the characteristic blue tint of the copper salt. No nitric acid was needed as the phosphorus in urine is almost entirely in the form of inorganic salts.

After cooling the contents of the flask were washed out into a 12 oz. beaker and diluted to 120 c.c. The sulphuric acid was then neutralized by ·88 ammonia, the point of neutralization being well shown by the deep blue colour of the copper ammonium compounds. The phosphoric acid in solution was estimated as follows: 25 c.c. nitric acid and 20 c.c. ammonia, S.G. 0·9, were added, and the heat of neutralization was sufficient to raise the solution to about 70° C. After cooling to 55° C. 40 c.c. 3 % solution of ammonium molybdate also at 55° C. was slowly poured into the beaker, the mixture being well stirred with a rubber topped rod. The yellow precipitate of ammonium phospho-molybdate was after cooling collected in a Gooch crucible, well washed with a 1 % solution of nitric acid, dried, placed in a nickel crucible and ignited to a dark blue tint, weighed and the percentage of P_2O_5 calculated.

In the case of the bread, milk and faeces, more rigorous oxidization was necessary on account of the comparatively large amount of organically combined phosphorus. 5 c.c. of milk, 2 grams of bread and ·25 gram faeces were taken and a few c.c. of sulphuric acid added. The mixture was heated until frothing ceased when potassium sulphate, copper sulphate and the remainder of the sulphuric acid were added and in addition 12 c.c. nitric acid. The flask was heated until red fumes were no longer given off. Repeated additions of nitric acid were made until all yellow tinge had disappeared, when all organic phosphorus was assumed to be converted to phosphoric acid and the estimation proceeded with as in the urine analysis.

From the data so obtained the total phosphorus intake and output were calculated. The butter-fat and sugar were free from phosphorus.

Phosphorus results in the white bread period.

Table XXI shows the intake and output of phosphorus expressed as P_2O_5 for the individuals for each day of the experiment. As each man's faeces for the whole period were mixed, the daily output of P_2O_5 under this head was obtained by dividing the total output by the number of days of the experiment.

The intake of P_2O_5 was fairly constant for each man, as pains were taken to ensure uniformity in the weights of the rations. In the case of Individuals I and IV, the daily output in the urine did not vary greatly, but II and III showed a falling off, which was especially marked in the case of II of the sixth day. The meaning of this falling off is obscure.

Table XXII shows the daily balance of P_2O_5 for each man throughout the experiment.

TABLE XXI. *Phosphorus (as P_2O_5). White Bread.*

	Grms. P_2O_5 in	Nov. 7	Nov. 8	Nov. 9	Nov. 10	Nov. 11	Nov. 12	Nov. 13	Total
I	Bread	1·34	1·31	1·31	1·39	1·28	1·17	1·31	9·11
	Milk	1·35	1·36	1·34	1·31	1·33	1·36	1·34	9·39
	Faeces	·62	·62	·62	·62	·62	·62	·62	4·34
	Urine	1·98	1·77	1·69	1·59	1·81	1·86	1·75	12·45
II	Bread	1·58	1·51	1·41	1·32	1·28	1·29	1·26	9·65
	Milk	1·35	1·36	1·34	1·31	1·33	1·36	1·34	9·39
	Faeces	·93	·93	·93	·93	·93	·93	·93	6·51
	Urine	2·58	2·61	2·34	2·39	2·34	1·82	1·79	15·87
III	Bread	1·56	1·45	1·56	1·35	1·56	1·45	1·26	10·19
	Milk	1·35	1·36	1·34	1·31	1·33	1·36	1·34	9·39
	Faeces	·68	·68	·68	·68	·68	·68	·68	4·76
	Urine	3·02	2·78	2·68	2·71	2·52	2·42	2·15	18·28
IV	Bread	1·38	1·39	1·37	1·35	1·30	1·17	1·31	9·27
	Milk	1·35	1·36	1·34	1·31	1·33	1·36	1·34	9·39
	Faeces	·44	·44	·44	·44	·44	·44	·44	3·08
	Urine	2·42	2·87	2·64	2 54	2·36	2·32	2·51	17·66

TABLE XXII. *Phosphorus Balance (as P_2O_5). White Bread.*

		Nov. 7	Nov. 8	Nov. 9	Nov. 10	Nov. 11	Nov. 12	Nov. 13	Total
I	Intake	2·69	2·67	2·65	2·70	2·61	2·53	2·65	18·50
	Output	2·60	2·39	2·31	2·21	2·43	2·48	2·37	16·79
	Balance	+·09	+·28	+·34	+·49	+·18	+·05	+·28	+1·71
II	Intake	2·93	2·87	2·76	2·63	2·61	2·65	2·60	19·04
	Output	3·51	3·54	3·27	3·32	3·27	2·75	2·72	22·38
	Balance	−·58	−·67	−·51	−·69	−·66	−·10	−·12	−3·34
III	Intake	2·91	2·81	2·90	2·66	2·89	2·81	2·60	19·58
	Output	3·70	3·46	3·36	3·39	3·20	3·10	2·83	23·04
	Balance	−·79	−·65	−·46	−·73	−·31	−·29	−·23	−3·46
IV	Intake	2·73	2·75	2·71	2·66	2·63	2·53	2·65	18·66
	Output	2·86	3·31	3·08	2·98	2·80	2·76	2·95	20·74
	Balance	−·13	−·56	−·37	−·32	−·17	−·23	−·30	−2·08

It is noteworthy that I differed from II, III and IV, a positive balance being shown for the whole period and for each day, while, in the case of the others, negative balances were shown for the whole period and for each of the days. This would indicate that the phosphorus requirements were satisfied in the case of I but not in the other three cases. It is perhaps hardly fair to base deductions on phosphorus requirements, since the unusual diet, near to or below a

https://doi.org/10.1017/S0022172400017095 Published online by Cambridge University Press

maintenance ration, might induce an abnormal metabolism of this element. Also on such a diet as this, the proportion of inorganic to organic phosphorus in the diet is rather higher than in an ordinary diet and it is certain that these forms of phosphorus are not of equal utility. The third period of the experiment indicates that the utilisation of inorganic phosphorus varies considerably for individuals.

Table XXIII shows the digestibility of the phosphorus in the rations over the whole period.

TABLE XXIII. *Phosphorus digestibility. White bread.*

Individual	Bread grms. dry	Total grms. P_2O_5	Bread grms. P_2O_5	Faeces grms. P_2O_5	P_2O_5 grms. digested	P_2O_5 total percentage digested	Percentage bread P_2O_5 digested assuming 100 % milk P_2O_5 digested
I	3443·7	18·5	9·11	4·34	14·16	76·5	52·3
II	3618·0	19·04	9·65	6·51	12·53	65·8	32·6
III	3853·0	19·58	10·19	4·76	14·82	75·6	53·2
IV	3481·1	18·66	9·27	3·08	15·58	83·5	66·7
Average	3598·9	18·94	9·55	4·67	14·27	75·3	51·2

The amount digested is obtained by subtracting that found in the faeces, and therefore unabsorbed, from the amount taken in with the food. The digestibility is expressed as P_2O_5 digested per 100 parts of P_2O_5 in the food.

Calculations were made of the digestibility for the whole of the phosphorus in the food and show an average digestibility of 75·3 %.

The individual figures, it will be seen, vary rather widely.

A further calculation was made in which the milk phosphorus was assumed to be completely digestible. This gives the digestibility of the bread phosphorus as 51·2 %, and the variations from the mean are in this case larger, a circumstance which may be the reflection of the differing powers of the individuals to utilise inorganic phosphorus.

Phosphorus results in the "standard" bread periods.

Table XXIV shows similarly the intake and output under each head.

It will be seen that "standard" bread is far richer in phosphorus than the white bread, since the figures in the table are for weights approximately equal to those in the case of the white bread period. This higher phosphorus content apparently results in the faeces being much richer in this element, and also in the phosphorus in the urine being well maintained in amount and at a higher rate of output than in the white bread period.

TABLE XXIV. *Phosphorus (as P_2O_5). "Standard" bread.*

	Grms. P_2O_5 in	Nov. 30	Dec. 1	Dec. 2	Dec. 3	Dec. 4	Dec. 5	Dec. 6	Total
I	Bread	2·74	2·74	2·86	2·64	2·75	2·55	2·66	18·94
	Milk	1·31	1·29	1·27	1·28	1·28	1·27	1·26	8·96
	Faeces	1·39	1·39	1·39	1·39	1·39	1·39	1·39	9·73
	Urine	2·40	2·11	2·28	2·47	2·80	2·72	2·50	17·28
II	Bread	2·96	3·24	3·11	2·86	2·75	2·84	2·60	20·36
	Milk	1·31	1·29	1·27	1·28	1·28	1·27	1·30	9·00
	Faeces	1·71	1·71	1·71	1·71	1·71	1·71	1·71	11·97
	Urine	2·58	2·70	2·80	2·59	2·78	2·88	2·90	19·23
III	Bread	3·20	3·01	3·53	3·07	3·20	3·06	3·00	22·07
	Milk	1·31	1·29	1·27	1·28	1·28	1·27	1·26	8·96
	Faeces	1·38	1·38	1·38	1·38	1·38	1·38	1·38	9·66
	Urine	3·74	3·39	3·62	3·22	3·62	3·48	3·42	24·49
IV	Bread	2·75	2·80	2·86	2·38	2·73	2·63	2·43	19·58
	Milk	1·31	1·29	1·27	1·28	1·28	1·27	1·26	8·96
	Faeces	1·09	1·09	1·09	1·09	1·09	1·09	1·09	7·63
	Urine	2·80	2·93	2·80	2·71	3·18	3·08	2·70	20·20

Table XXV shows the balances for phosphorus in this period.

TABLE XXV. *Phosphorus balance (as P_2O_5). "Standard" bread.*

		Nov. 30	Dec. 1	Dec. 2	Dec. 3	Dec. 4	Dec. 5	Dec. 6	Total
I	Intake	4·05	4·03	4·13	3·92	4·03	3·82	3·92	27·90
	Output	3·79	3·50	3·67	3·86	4·19	4·11	3·89	27·01
	Balance	+ ·26	+ ·53	+ ·46	+ ·06	− ·16	− ·29	+ ·03	+ ·89
II	Intake	4·27	4·53	4·38	4·14	4·03	4·11	3·90	29·36
	Output	4·29	4·41	4·51	4·30	4·49	4·59	4·61	31·10
	Balance	− ·02	+ ·12	− ·13	− ·16	− ·46	− ·48	− ·71	− 1·74
III	Intake	4·51	4·30	4·80	4·35	4·48	4·33	4·26	31·03
	Output	5·12	4·77	5·00	4·58	5·0	4·86	4·80	34·15
	Balance	− ·60	− ·47	− ·20	− ·23	− ·52	− ·53	− ·54	− 3·12
IV	Intake	4·06	4·09	4·13	3·66	4·01	3·90	3·69	27·54
	Output	3·89	4·02	3·89	3·80	4·27	4·17	3·79	27·83
	Balance	+ ·17	+ ·07	+ ·24	− ·14	− ·26	− ·27	− ·10	− ·29

These results are very interesting as a positive balance is again shown for Individual I and negative balances for the others. In this period, however, I shows two days with negative balances, while II and

IV have days with positive balances. In this period, Individual I shows a smaller positive balance, and II, III and IV, smaller negative balances than in the first period. IV's negative balance is exceedingly small, being only ·29 grm. P_2O_5.

Table XXVI shows the digestibility of phosphorus for period II.

TABLE XXVI. *Phosphorus digestibility. "Standard" bread.*

Individual	Bread grms. dry	Total grms. P_2O_5	Bread grms. P_2O_5	Faeces grms. P_2O_5	P_2O_5 grms. digested	P_2O_5 total percentage digested	Percentage bread P_2O_5 digested assuming 100 % milk P_2O_5 digested
I	3449·5	27·90	18·94	9·73	18·17	65·1	48·6
II	3786·8	29·36	20·36	11·97	17·39	59·2	41·2
III	4014·2	31·03	22·07	9·66	21·37	68·8	56·2
IV	3372·0	27·54	18·58	7·63	19·91	72·3	58·9
Average	3655·6	28·96	19·99	9·75	19·21	66·3	51·2

This table shows that the availability of phosphorus in the "standard" bread ration is almost the same as in the white bread ration, the individuals showing smaller variations. The digestibility of the bread phosphorus, assuming the milk phosphorus entirely digestible, is 51·5 %, exactly the same as in the case of the white bread.

Tables XXVII and XXVIII show the total phosphorus taken in and excreted during the three parts of the third period where coarser wholemeal flours were used and only two individuals took part in the experiment. The table shows the great increase in the total amount of phosphorus caused by the retention of the extra amount of bran in the meal, the percentage of phosphorus being nearly double that in the flour used in the second period of the experiment.

TABLE XXVII. *Phosphorus as* P_2O_5.

	Grms. P_2O_5 in	First 3 days	Second 3 days	Third 3 days
II	Bread	12·64	12·24	12·08
	Milk	3·91	3·87	3·96
	Faeces	8·63	7·50	11·15
	Urine	9·81	9·32	10·41
IV	Bread	12·25	11·87	12·06
	Milk	3·91	3·87	3·96
	Faeces	6·17	6·84	6·26
	Urine	9·55	10·10	11·19

https://doi.org/10.1017/S0022172400017095 Published online by Cambridge University Press

TABLE XXVIII. *Phosphorus balance (as* P_2O_5*).*
92 °/₀ *and* 88 °/₀ *meals.*

		First 3 days	Second 3 days	Third 3 days
II	Intake	16·55	16·11	19·88
	Output	18·44	16·82	21·56
	Balance	−1·89	−·71	−1·68
IV	Intake	16·16	15·74	19·86
	Output	15·72	16·94	17·45
	Balance	+·44	−1·20	+2·41

TABLE XXIX. *Phosphorus digestibility.* 92 °/₀ *meal.*

Three day period.

Individual	Bread grms. dry	Total grms. P_2O_5	Bread grms. P_2O_5	Faeces grms. P_2O_5	P_2O_5 grms. digested	P_2O_5 total percentage digested	Percent. digested assuming 100 °/₀ milk P_2O_5 digested
II	1456·3	16·55	12·64	8·63	7·92	47·8	31·7
IV	1410·9	16·16	12·25	6·17	9·99	61·8	49·6
Average	1433·6	16·35	12·44	7·40	8·95	54·8	40·6

TABLE XXX. *Phosphorus digestibility.* 88 °/₀ *meal.*

Three day period.

Individual	Bread grms. dry	Total grms. P_2O_5	Bread grms. P_2O_5	Faeces grms. P_2O_5	P_2O_5 grms. digested	P_2O_5 total percentage digested	Percent. digested assuming 100 °/₀ milk P_2O_5 digested
II	1352·9	16·11	12·24	7·50	8·61	53·4	38·7
IV	1301·1	15·74	11·87	6·84	8·90	62·9	42·3
Average	1327·0	15·92	12·05	7·17	8·75	58·2	40·5

TABLE XXXI.

Phosphorus digestibility. 88 °/₀ *meal* + 9 *grms. bone ash* (3·84 *grms.* P_2O_5).

Three day period.

Individual	Bread grms. dry	Total grms. P_2O_5	Bread grms. P_2O_5	Faeces grms. P_2O_5	P_2O_5 grms. digested	P_2O_5 total percentage digested	P_2O_5 in bone-ash digested
II	1399·2	19·88	12·08	11·15	8·73	43·90	3·84
IV	1397·5	19·86	12·06	6·26	13·60	68·40	3·84
Average	1398·3	19·87	12·07	8·70	11·16	56·10	3·84

The large amount in the faeces indicates that the extra phosphorus is not proportionately absorbed, and Individual II seemed quite unable to take up the phosphorus and showed a considerable negative balance losing 2·6 grms. in the first two periods. Individual IV showed also a negative balance on the six days total although he was apparently retaining phosphorus in period I.

The last period when 9 grms. of bone ash were added to the ration again shows the marked inability of Individual II to make use of a heavy phosphorus ration, an increase in the faeces of more than the total bone ash phosphate fed being shown. Individual IV on the other hand took up an extra amount of phosphorus about equal to the bone ash content and exhibits a large plus balance.

On the whole it may be said that the results are too widely divergent to base an opinion on, but they indicate that a longer period and more men are necessary to demonstrate results of any value.

The main purpose of the experiments described in this paper was to test the relative digestibility of white and "standard" breads. The details of the experimental procedure were arranged in accordance with this intention, and the results bear with completeness on this point alone. Thus the amount of food consumed by each of the four individuals who took part in the experiments was approximately the same, and was not adjusted to the body-weight as it should have been had the actual nutritive value of the breads been under investigation. The period chosen for the observations (7 days), while longer than those usually employed for digestibility experiments on Man, and long enough to call for some self-sacrifice on the part of the subjects, was too short to yield nutrition balances upon which definite conclusions can be based. Nevertheless, the effects of the bread diet upon the metabolic balance-sheet for short periods are not without interest, and are discussed in the paper.

With regard to digestibility, the information given by the experiments may be looked upon as conclusive. The four individuals who ate the breads varied greatly in physical type, and the two forms of bread were eaten by all under strictly comparable conditions.

As measured by energy and protein the degree of absorption in different individuals showed marked uniformity. In the case of phosphorus one individual showed a degree of absorption which was considerably less than that of the other subjects. The results as a whole lend no support to any extreme view as to the advantages or disadvantages possessed by standard bread; at any rate as regards the availability of the main, and more familiar food constituents.

With respect to the availability of their total energy white bread and standard bread differ but little. With regard to protein there is a distinct advantage on the side of white bread, some 3½ per cent. more of its nitrogen-content being absorbed.

On the other hand, the experiments lend no support to the belief that the phosphorus compounds of bread of the "standard" type are worse absorbed than those of white bread, so that the former contains an appreciably larger amount, not only of total, but of available phosphorus. The ratio of available phosphorus to available nitrogen stands, in the case of the standard bread, nearer to the ratio present in efficient mixed dietaries, a circumstance, however, which only becomes of practical significance when bread forms a large proportion of a person's dietary.

Experiments lasting for a shorter period (3 days) were carried out upon two of the subjects with two breads containing a larger proportion of the whole wheat berry than so-called "standard" bread. In these the availability of both the nitrogen and phosphorus present proved to be decidedly less. It may be pointed out, however, that the averages obtained do not compare quite satisfactorily with the averages from the white and standard breads, since it happens that one of the two individuals who proceeded to this further test (Individual II) displayed throughout—in the case of all the breads—a lower absorption coefficient (especially for phosphorus) than any of the other subjects. With regard to the possible importance and special nutritive influence of unknown constituents present in the cortex of wheat, the experiments described yield no evidence. The periods were of course much too short, and, moreover, to judge from the available knowledge on the matter, the milk taken would supply an equivalent for such factors. They can only be of practical importance in cases where bread forms a very large proportion of the total dietary, and their influence can only be tested by long observations carried out on special communities.

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