LXII. EXPERIMENTS ON NUTRITION. IX.

COMPARATIVE VITAMIN B VALUES OF FOODSTUFFS. PULSES AND NUTS.

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THE good value of the "katjang-idjo" bean (*Phaseolus radiatus*) as a preventive and curative of beriberi was described by Grijns [1901]. Cooper [1912] and Chick and Hume [1917] subsequently made some quantitative tests with lentils and dried peas. The comparative values of these two pulses, with wheat germ as 100, was given in the Report on accessory food factors of the Medical Research Council (1924) as 80 and 40. Cajori [1920] found that the addition of 1 g. of various nuts to the diet restored growth to rats declining in weight. Observations by McCollum, Simmonds and Pitz [1917] on the nutritive value of the white bean led to the statement that 25 % of the bean in the diet of rats furnished sufficient vitamin B. Similar experiments with the soya bean by Daniels and Nichols [1917] and with the peanut by Daniels and Loughlin [1918] showed that 50 and 56 % of these foods supplied enough vitamin B for the rat. Also, Johns, Finks and Paul [1919] found that 75 % of coconut press cake had enough vitamin B for the rat.

In view of the scanty information about these foodstuffs in regard to their vitamin B content, and in order to obtain their comparative values more closely, we have undertaken this series of experiments. Our results must at present be considered as the vitamin B₁ + vitamin B₂ value, though the symptom of polyneuritis has been taken as far as possible as the criterion of the amount of vitamin in the foods. As our method of testing foodstuffs for vitamin B is very laborious the work has been limited to the more common varieties of pulses and nuts.

EXPERIMENTAL.

As in our former testing of foodstuffs for vitamin B [Plimmer, Rosedale, Raymond and Lowndes, 1927] pigeons have been used. They have been kept in pairs in suitably sized cages on the roof of the building. The earlier experiments were made with the foodstuff mixed with white rice and fish meal and with rearing as the standard of the vitamin B value. As the series of tests extended it was noticed that the birds scattered and separated the mixture

and so white flour was used in place of white rice. The ingredients were mixed into a dough and the dough divided into pills which were dried in the air, or at 37°. This mixture could not be separated, and thus the birds had to eat the mixture required for experimentation. The standard of rearing was considered too high and the standard of maintenance for at least 26 weeks was substituted. It had often been found that a period of 15 weeks was not long enough, and occasionally birds were observed to suffer from polyneuritis after as long a time as 30 weeks.

The result with each foodstuff is given shortly together with the times of the experiment and the weights, etc., in the tables.

Split peas.

In the first trial the birds were on the split pea diet for 106 weeks and showed no signs of any ill-effect. The other tests showed that for maintenance the diet must contain 30 % split peas. Rearing was possible on 40 %, but precarious, and not improved on raising to 50 %. Table I gives the details.

Table I. *Split peas.*

Date	Time in weeks	Diet			Weights, g.		Number of eggs	Result
		Split peas	White rice	Fish meal	Cock No. 25/15	Hen No. 25/10		
17. vi. 25		40	55	5	410	350	22 in Sept., Nov., Feb., Mar., Apr., May, June, July, Sept.	First 2 hatched and reared; 2 unfertile; 4 deserted; 9 fer- tile and deserted; 5 hatched and died in 2nd week
to								
12. x. 26	69				495	410	2 in Nov.	Both hatched and died in 1st week
13. x. 26		50	45	5				
to								
4. i. 27	12				515	435		
			White flour					
5. i. 27		40	55	5			10 in Feb., Mar., Apr., May	All fertile and de- serted
to								
31. v. 27	21				480	390		
1. vi. 27		50	45	5			2 in June	Deserted
to								
28. vi. 27	4				485	430		
					No. 26/28	No. 26/30		
29. i. 27		30	65	5	415	505	16 in Mar., Apr., May, June, July	All were broken and deserted, some were fertile
to								
22. vii. 27	25				420	430		
					No. 21	No. 25/34		
20. i. 27		20	75	5	480	500	None	Both birds showed paralysis, but only hen seen with re- tracted head. Died
to								
13. ii. 27	4				310	315		
					No. 9	No. 10		
16. xii. 26		10	85	5	465	465	None	Both paralysed. Cock but not hen seen with retracted head. Died
to								
17. i. 27	5				390	290		

Whole dried green peas.

The first test was started at the same time as that with split peas. The pair were on the diet for 87 weeks altogether and on changing to white flour for another 15 weeks. The pair of birds, previously on 30 % split peas, after a period on brown rice, were given a diet with 30 % green peas to test for maintenance. They remained for 27 weeks in good condition. There seemed thus no difference between whole green peas and split peas and no further trial of green peas was then made. The tests with green peas at 20 % and 10 % were made later (Table II), and showed that 30 % dried green peas was the minimum for maintenance and that the husk contained no greater concentration of vitamin B than the endosperm.

Table II. *Whole dried green peas.*

Date	Time in weeks	Diet			Weights, g.		Number of eggs	Result
		Green peas	White rice	Fish meal	Cock No. 25/1	Hen No. 25/13		
17. vi. 25 to 1. vi. 26	50	40	55	5	365	315	14 in Sept., Oct., Dec., Feb., Apr., May	6 hatched and reared; 4 fertile and de- serted; 4 unfertile
2. vi. 26 to 28. ix. 26	17	30	65	5	410	350	15 in June, July, Aug., Sept.	All deserted; some fertile
29. ix. 26 to 15. ii. 27	20	40	55	5	450	360	4 in Oct.	All deserted
			White flour					
16. ii. 27 to 31. v. 27	15	40	55	5	490	400	12 in Feb., Mar., Apr., May	All deserted
1. vi. 27 to 28. vi. 27	4	50	45	5	390	350	4 in June	All deserted
					420	360		
					No. 26/28	No. 26/30		
14. ix. 27 to 21. iii. 28	27	30	65	5	410	435	10 in Oct., Feb., Mar.	2 hatched and died in 1st week; 8 de- serted.
					450	485		
					No. 96	No. 65		
10. x. 28 to 9. i. 29	13	20	75	5	395	405	None	
					375	385		
3. iv. 29 to 24. iv. 29	25				340	310		Hen died with large heart. Cock showed retracted head, and died
	28				300			
					No. 77	No. 128		
30. i. 29 to 13. iii. 29	6	10	85	5	495	445		
					320	320	None	Both showed para- lysis, the cock with retracted head. Both died in 7th week

Lentils.

Altogether the pair of birds were kept 79 weeks on lentils and rice. There was an improvement in rearing on raising to 50 % lentils.

The trial with 20 % lentils was made on the birds previously used with split peas. They were given brown rice in the interval.

The details given in Table III show that for maintenance 30 % lentils are required. Rearing was scarcely possible on 40 %, but fairly good on 50 %.

Table III. *Lentils.*

Date	Time in weeks	Diet			Weights, g.		Number of eggs	Result
		Lentils	White rice	Fish meal	Cock No. 33	Hen No. 25/5		
5. viii. 25 to 29. vi. 26	47	40	55	5	420	355	9 in Nov., Mar., Apr., May	2 unfertile; 3 hatched and died; 1 reared but abnormal; 1 dead at hatch; 2 fertile, deserted
30. vi. 26 to 8. ii. 27	32	50	45	5	420	440	7 in July, Aug., Sept., Oct.	2 hatched and died; 2 hatched and rear- ed; 3 fertile, de- serted
9. ii. 27 to 1. vi. 27	17	40	White flour 55	5	450 420	510 440	5 in Mar., Apr., May	All deserted. Birds escaped
9. ii. 27 to 22. vi. 27	19	30	65	5	No. 75 430 380	No. 70 435 425	6 in May, June, July	All deserted. Hen escaped
6. vii. 27 to 25. viii. 27	7				No. 54 395 410	340 370	2 in July	Deserted
18. viii. 27 to 12. x. 27	8	20	75	5	No. 25/15 475 395	No. 25/10 395 285	2 in Aug.	Deserted. Both birds showed retracted head and were cured

Haricot beans.

The first pair of birds did not like the beans and only ate them if compelled by not getting a new supply of food until the old had been cleared up.

The tests as given in Table IV showed that 40 % was required for maintenance.

The same pair, after a period of about 5 weeks on wheat, were started on 30 % haricot beans. At death both birds were found to have tumours.

Table IV. *Haricot beans.*

Date	Time in weeks	Diet			Weights, g.		Number of eggs	Result
		Haricot beans	White rice	Fish meal	Cock No. 25/14	Hen No. 25/19		
1. vii. 25 to 13. x. 25	15	40	55	5	360	345		
23. xii. 25	25				230	315	None	Cock ill, chloro- formed
						275		Hen ill, chloroformed
			White flour		No. 5	No. 4		
2. iii. 27 to 10. viii. 27	23	40	55	5	435	375	18 in Mar., Apr., May, June, July	Generally deserted after a few days, some found fertile
					440	395		
					No. 84	No. 37		
24. xi. 27 to 4. i. 28	6	20	75	5	450	400		
4. iv. 28	20				320	320	None	Cock died with very wet tissues
						325		Hen died with typical polyneuritis
					No. 5	No. 4		
15. ix. 27 to 9. i. 28	17	30	65	5	425	425	6 in Sept., Oct.	Deserted
					475	340		Hen died with growth in oviduct
						No. 69		
29. ii. 28 to 18. v. 28	24				445	305	9 in Mar., Apr., May, June	All deserted
12. ix. 28	28				305	340		Cock died; tumour in testis
						295		Hen showed signs of polyneuritis

Table V. *Soya beans.*

Date	Time in weeks	Diet			Weights, g.		Number of eggs	Result
		Soya beans	White flour	Fish meal	Cock No. 52	Hen No. 42		
8. ii. 28 to 22. viii. 28	28	30	65	5	490	530	10 in Apr., May, June, July, Aug.	All unfertile
					425	500		
					No. 100	No. 233		
24. iv. 28 to 27. vi. 28	9	40	55	5	410	425	4 in May, June	1 fertile; 3 unfertile
28. vi. 28 to 7. xi. 28	19	20	75	5	415	475	2 in July	Hatched and died
20. i. 29	31				345	370		Hen slightly para- lysed and died; cock better
					420			
					No. 37	No. 332		
17. x. 28 to 14. xi. 28	4	10	85	5	445	385	None	Both showed paraly- sis in 5th week; hen with retracted head
					315	315		

Soya beans.

The details in Table V tend to indicate that 20 % soya bean suffices for maintenance. On this quantity the birds began to lose weight, but slowly regained it. The hen in the 18th week suffered from an eye infection and died. Both birds ate very little during the time of the experiment and never looked really well. We have several times noticed that pigeons which eat little can maintain themselves on a diet with just too little vitamin B for a long time but not indefinitely. It cannot be considered that 20 % soya bean is enough; 30 % is nearer the minimum quantity.

Peanuts.

The test of peanuts is shown in Table VI.

20 % is enough for maintenance; rearing was possible on 40 %. Similar figures, twice as much vitamin B being required for rearing as is needed for maintenance, have been found in previous experiments.

Table VI. *Peanuts.*

Date	Time in weeks	Diet			Weights, g.		Number of eggs	Result
		Pea- nuts	White rice	Fish meal	Cock No. 25/26	Hen No. 43		
26. ii. 26		40	55	5	455	430	8 in Mar.,	5 hatched and reared;
to							May, July,	1 hatched and died;
29. ix. 26	31				430	415	Aug.	1 added; 1 unfertile
30. ix. 26		30	65	5			1 in Oct.	Fertile, deserted
to								
9. ii. 27	19				490	485		
			White flour					
10. ii. 27		30	65	5				
to						No. 23		Hen escaped
9. iii. 27	4				465	450	4 in Apr.,	New hen.
to							May	Fertile, deserted
25. v. 27	15				360	480		Cock not well; ex- periment stopped
					No. 83	No. 25/27		
23. ii. 27		20	75	5	410	385	16 in Feb.,	3 hatched and died;
to							Mar., Apr.,	1 hatched and rear- ed; 12 fertile, de- serted
24. viii. 27	26				390	350	June, July, Aug.	
					No. 83	No. 25/27		
6. x. 27		30	65	5	415	390	10 in Oct.,	2 hatched and died;
to							Nov., Dec.,	7 fertile; 1 unfertile, deserted. Hen sud- denly not well; ex- periment stopped
14. iii. 28	23				435	280	Jan., Feb.	
					No. 88	No. 25/5		
16. vi. 27		10	85	5	395	405	2 in July	Unfertile, deserted
to								
31. viii. 27	11				360	325		Hen had polyneuritis and died
to								Cock had polyneuritis and was cured with 1 g. of wheat germ ("bemax")
2. xi. 27	20				325			

Almonds.

The vitamin B value of almonds was tested both with ground almonds, such as are used in making cakes, and with whole almonds, which were put through a mincer before being incorporated with white flour and fish meal. The two varieties were used to ascertain if the skin contained any vitamin B (see Table VII).

The first pair of birds were on the ground almond diet for 72 weeks in all. The other pairs on smaller amounts of ground almonds indicated that 40 % was required for maintenance.

The experiments with whole almonds (Table VIII) were started with 20 % and 30 % in the diet, the one with 40 % after the other results were known.

The minimum quantity of whole almonds for maintenance was thus 40 %, the same as with ground almonds. The skins do not appear to contain more vitamin B than the rest of the seed.

Table VII. *Ground almonds.*

Date	Time in weeks	Diet			Weights, g.		Number of eggs	Result
		Ground almonds	White rice	Fish meal	Cock No. 1	Hen No. 5209		
1. iv. 26		40	55	5	485	420	8 in Apr., May, June	2 unfertile; 6 fertile; no hatching
to 14. vii. 26	15				445	400		
15. vii. 26		50	45	5			8 in July, Aug., Oct., Mar.	All fertile; 1 hatched and died
to 9. iii. 27	34				490	480		
			White flour					
10. iii. 27		50	45	5			6 in Apr., May	All deserted; some fertile
to 25. v. 27	11				470	410		
26. v. 27		60	35	5			8 in June, July, Aug.	All fertile, deserted
to 24. viii. 27	12				470	440		
					No. 89	No. 49		
9. xi. 27		40	55	5	385	370	14 in Dec., Jan., Feb., Mar., Apr., May	Mostly fertile, no hatching
to 14. iii. 28	18				400	365		Cock had head re- traction in 17th week and was cured by 1 g. of dried yeast and remained well
to 20. vi. 28	32				380	350		
					No. 76	No. 449		
1. ix. 27		30	65	5	435	485		Cock had head re- traction in 9th week and died; hen ill, but recovered
to 26. x. 27	8				425	410		
to 8. ii. 28	19					430		
					No. 63	No. 92		
9. ii. 28		30	65	5	440	420		Both birds had head retraction and died
to 4. iv. 28	8				280	275		
					No. 76	No. 16		
23. vi. 27		20	75	5	420	325		Both birds showed head retraction and were cured
to 20. vii. 27	4				290	260		

Table VIII. *Whole almonds.*

Date	Time in weeks	Diet			Weights, g.		Number of eggs	Result
		Whole almonds	White flour	Fish meal	Cock No. 67	Hen No. 128		
15. iii. 28 to 23. v. 28	10	30	65	5	380	425	2 in Mar.	Both hatched and died in 1st week with large hearts and wet tissues Cock died 25. iii. 28 with paralysis, but head not seen retracted. Hen had head retracted on 29. v. 28 and was cured with 0.75 g. dried yeast
					No. 83	No. 294		
25. iv. 28 to 23. v. 28	5	20	75	5	415	415	2 in Apr.	Deserted Cock had head retracted in 5th week and was cured with 0.5 g. dried yeast. Hen had head retracted in 6th week and was cured with 0.5 g. wheat germ
					No. 2569	No. 50		
17. v. 28 to 31. x. 28	24	40	55	5	345	470	2 in May	1 unfertile; 1 fertile, deserted Cock escaped
14. xi. 28	26				375	435		
						465		

Table IX. *Hazel nuts.*

Date	Time in weeks	Diet			Weights, g.		Number of eggs	Result
		Hazel nuts	White flour	Fish meal	Cock No. 57	Hen No. 6		
7. xii. 27 to 13. vi. 28	27	30	65	5	520	475	6 in Mar., Apr., May	All fertile; 5 hatched and died
					475	395		
					No. 96	No. 65		
28. i. 27 to 8. viii. 28	32	20	75	5	380	425	8 in Mar., Apr., May, June	2 unfertile; 6 fertile, all deserted
22. viii. 28	34				350	275		
					330	365		Hen showed polyneuritis; cured with 1 g. wheat germ
					No. 57	No. 6		
13. vi. 28 to 4. vii. 28	3	10	85	5	475	395		
					350	300		Both had polyneuritis and both cured with 0.5 g. marmite

Hazel nuts.

The test of hazel nuts is shown in Table IX. The pair on 30 % after a period of 27 weeks were then given 10 %. The minimum quantity for maintenance of

adult pigeons thus seemed to be 20 %. It may be noted that the hen became ill after 30 weeks and showed polyneuritis. This was possibly the result of laying so many eggs.

Chestnut.

For the purpose of these experiments dried chestnuts were used, as they could be obtained during almost the whole year, and as they were in this state more easily comparable with almonds and hazel nuts.

As a preliminary to the trial a pair of birds were given the dried chestnut with 5 % fish meal to see if they would eat it. It was eaten well and the birds increased in weight. In the first trial the birds were on the chestnut diet for 75 weeks. They were then given a diet of brown rice with 5 % fish meal and later tried with 30 % chestnut. Table X shows that the quantity of dried chestnut for maintenance is 40 %. Some rearing was possible on this amount, but it was better with 50 %.

Table X. *Chestnut.*

Date	Time in weeks	Diet			Weights, g.		Number of eggs	Result
		Chest- nut	White rice	Fish meal	Cock No. 7	Hen No. 8		
10. ii. 26 to 3. iii. 26	3	95	0	5	500	385		
4. iii. 26 to 9. vi. 26	14	50	45	5	555	445	4 in Mar., Apr.	All hatched and reared
10. vi. 26 to 16. iii. 27	40	40	55	5	465	380	14 in June, July, Aug., Sept., Feb.	2 hatched and rear- ed; 3 unfertile; 9 fertile, deserted
			White flour		505	425		
17. iii. 27 to 1. vi. 27	11	40	55	5	445	405	10 in Mar., Apr., May	All deserted
2. vi. 27 to 10. viii. 27	10	50	45	5	455	385	5 in June, July	All deserted
			Brown rice					
11. viii. 27 to 5. x. 27	8	0	95	5	510	430		
			White flour		No. 14	No. 13		
24. viii. 27 to 20. ix. 27	4	20	75	5	450	395	2 in Aug.	Deserted
to 26. x. 27	10				335	285		Cock showed retract- ed head. Cured with 1 g. wheat germ
						260		Hen had paralysis and died
					No. 7	No. 8		
6. x. 27 to 23. xi. 27	7	30	65	5	420	340	2 in Oct.	Deserted
to 30. xi. 27	8				420	330		Cock showed retract- ed head. Cured with 1 g. of wheat germ
								Hen showed retract- ed head. Cured with 1 g. of wheat germ

Coconut.

The coconut used in these experiments was the material commonly employed for making cakes and sweets, and consisted of the dried and flaked flesh of the nut.

It was expected that this food would show about the same value as the other nuts, and the first trial was made with 40 % mixed with white rice. The birds did not appear to eat the coconut, and after 6 weeks the trial was stopped as the birds had lost weight and looked ill. They were put upon millet, their former diet, for the next 3 weeks and were then given coconut mixed with 5 % fish meal. The food was not liked and little was eaten. Both birds showed paralysis and died.

Table XI. *Coconut.*

Date	Time in weeks	Diet			Weights, g.		Number of eggs	Result
		Coco- nut	White rice	Fish meal	Cock No. 15	Hen No. 16		
27. i. 26 to 10. iii. 26	6	40	55	5	495	430		Ate mostly rice
31. iii. 26 to 28. iv. 26	4	95	0	5	405	425		
23. vi. 26	12				335	355		Cock showed retract- ed head and died
						280		Hen showed paraly- sis and died
					No. 25/14	No. 25/27		
2. vi. 26 to 7. vii. 26	5	95	0	5	365	345		
21. vii. 26	7				290	285		Cock showed retract- ed head and died
						245		Hen showed retract- ed head. Cured with 1 g. yeast

Table XII. *Coffee.*

Date	Time in weeks	Diet			Weights, g.		Number of eggs	Result
		Green coffee	White rice	Fish meal	Cock No. 7	Hen No. 8		
5. i. 28 to 29. ii. 28	8	30	65	5	600	445		
21. iii. 28 to 28. iii. 28	11				345	305		Cock showed retract- ed head. Cured with 1 g. wheat germ
	12				325	285		Cock died
						255		Hen was paralysed and died
		Roasted coffee			No. 39	No. 50		
29. xii. 27 to 1. ii. 28	5	30	65	5	380	455		
					225	305		Both birds died
10. ii. 28 to 9. iii. 28	4	50	45	5	No. 84 370	No. 62 385		
					245	255		Both birds died

As coconut is such a common foodstuff one more trial was made. The former result was confirmed (see Table XI).

The flesh of the coconut, as prepared for making cakes, thus appeared to contain no vitamin B.

Coffee.

It was not expected that roasted coffee would contain vitamin B, but it was felt necessary to try the experiment. Two experiments were made with 30 and 50 % coffee. The birds died after the 5th and 4th weeks respectively.

At the same time a trial was made with 30 % green coffee. As the birds lived for 8 to 12 weeks it would appear that green coffee contained some vitamin B. A higher proportion in the diet was not tried. The vitamin in the seed is thus destroyed during the roasting (see Table XII).

DISCUSSION AND SUMMARY.

Previous work upon the vitamin B value of pulses and nuts suggested that the pulses had varying values, but that nuts were of more uniform value. Our results do not support the older observations. Pulses have been found to have a very similar vitamin B value, whilst nuts showed considerable variation. Hazel nuts were of highest value, coconut was of no value.

It is convenient to adopt a standard for comparison. In our former work [1927] dried yeast was taken as standard. 4 % of this food was found sufficient to maintain a pair of pigeons for 26 weeks or longer. It was placed at 100. Using the same standard the pulses and nuts now tested come out as follows.

	Percentage amount in diet for maintenance	Relative vitamin B value
Dried yeast	4	100
Split peas	30	13
Whole dried green peas	30	13
Lentils	30	13
Haricot beans	40	10
Soya beans	30	13
Peanuts	20	20
Ground almonds	40	10
Whole almonds	40	10
Hazel nuts	20	20
Dried chestnuts	40	10
Coconut	No maintenance	0
Coffee, green	Over 30	Less than 13
Coffee, roasted	No maintenance	0

These figures do not compare strictly with those given for cereals in our former work, as the standard of hatching and rearing was then taken as criterion of the vitamin B value. The values of cereals are being re-determined on the standard of maintenance for a period of at least 26 weeks. The amount of whole wheat for maintenance has been found to be 40 %, whilst oatmeal and maize are showing 50 %, a higher value than was expected. Other tests are being made with fruits and vegetables. Potatoes and artichokes

at 80 % and parsnips and leeks at 60 % of the diet have been found to maintain pigeons for long periods. The other vegetables and fruits have no appreciable quantity of vitamin B.

In these experiments it has again been observed that for hatching and rearing of young pigeons more vitamin B is required than for maintenance. In many cases rearing has been possible on double the amount needed for maintenance.

As it is not possible at present in the case of these foodstuffs to differentiate vitamin B into B₁ and B₂ factors, the results must be considered as due to the two factors together, though the symptoms of polyneuritis have been taken as the indication of the value. Loss of weight cannot be regarded as an indication of vitamin B₂ value. As soon as the food mixture is not suitable for maintenance of the pigeons, consumption of the food gets less and less and the birds lose weight in consequence. Polyneuritis has never been observed without refusal of the birds to eat. Both Cooper, and Chick and Hume, have mentioned quantities of foodstuffs required to prevent loss of weight of pigeons, but our experience indicates that continuation of their experiments for a longer period would have led to polyneuritis.

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