On Japanese Foods
Report 3

Ryozo HIROHATA
From Laboratory of Protein Chemistry, Yamaguchi Medical School
(Received June 4, 1962)

II. On Legumes, with Special Reference to the Soy-bean

1. Some common pulses in Japan.

The Japanese live generally on protein-deficient foods, at least on foods poor in protein of good quality, as described in a previous report, so that they naturally appreciate legumes as source of proteins. I. Onishi[34] and M. Fujii[35] estimated, each in 5 humans, the absorbability of some of the legumes produced and eaten in Japan, with the result shown in Table 23.

Tab. 23. Chemical composition and absorption rate of some legumes (M±δ, %).

Legume	Crude protein		Crude fat		Crude solub. carbohydrate		Crude fibre	
	Content	Abspt. rate	Content	Abspt. rate	Content	Abspt. rate	Content	Excretion rate
Pisum sativum (fresh)	7.11	82.62 ± 5.21	0.63	69.25 ± 7.56	18.32	97.84 ± 0.36	2.32	38.57 ± 5.13
Phaseolus mungo	22.08	68.85 ± 1.16	1.68	68.71 ± 4.29	54.29	92.63 ± 0.57	3.90	58.92 ± 3.96
〃 radiatus	21.42	76.88 ± 4.92	1.29	77.72 ± 7.16	52.01	93.30 ± 0.63	4.30	53.70 ± 11.76
Dolichos lablab	23.70	78.43 ± 1.63	1.14	76.91 ± 3.20	56.50	94.24 ± 1.96	3.84	57.78 ± 3.97
Vigna catjang	24.13	81.93 ± 1.88	2.18	82.85 ± 5.93	50.48	95.10 ± 2.36	4.50	55.31 ± 4.23
Arachis hypogaea	26.07	95.66 ± 2.01	48.03	92.17 ± 1.13	16.65	95.49 ± 1.94	1.49	69.99 ± 4.15
Vicia faba (fresh)	9.69	74.30 ± 3.89	0.71	71.76 ± 6.79	16.56	97.91 ± 0.56	2.33	68.93 ± 7.06
Glycine hispida	32.85	71.44 ± 0.74	17.65	73.46 ± 1.00	25.98	98.10 ± 1.05	4.47	54.11 ± 4.96

In Japan the peas and beans are of course eaten merely boild, but they are also taken in two different preparations peculiar to the Japanese, "moyashi", mung bean malt, and "natto", soy-beans steamed and fermented with Bac. natto. The chemical composition and absorbability of these preparations may be tabulated as follows:

The absorbability of these two kinds of beans in their original form and in these particular preparations is shown in Table 25, the values given having been deter-

Tab. 24. Chemical composition and absorption rate of two bean preparations (M±δ, %).

Preparation	Crude protein		Crude fat		Carbohydrate		Crude fibre	
	Content	Abspt. rate	Content	Abspt. rate	Content	Abspt. rate	Content	Excretion rate
"Moyashi" of Ph. mungo	2.61	91.36 ± 3.14	0.17	86.07 ± 2.61	1.31	94.54 ± 0.85	0.60	84.72 ± 3.92
"Natto" of soy-bean	19.31	81.01 ± 1.95	11.04	82.28 ± 1.20	7.68	97.49 ± 1.08	1.21	53.26 ± 5.96

mined on the assumption, or rather from the common fact, that 100 g of mung beans yields 772 g of "moyashi" and the same amount of soy-beans 191.2 g of "natto".

Tab. 25. The absorbability of Phaseolus mungo and Glycine hispida eaten in their original form and in their particular preparations (moyashi and natto) (g).

	Crude protein	Crude fat	Crude solub. carbohydrate	Crude fiber
100g Phaseol. mungo	15.20	1.15	50.28	2.29
772g Malt of Ph. mungo	18.39	1.11	9.45	3.91
Difference	+3.10	−0.03	−40.83	+1.61
100g Glyc. hispida	23.47	12.97	25.49	2.05
191.2g Natto of Glyc. hisp.	24.32	12.92	20.34	1.08
Difference	+0.85	−0.05	−5.15	−0.97

The main sources of vegetable protein in common Japanese diets are rice and other cereals, the soy-bean and its preparations such as "natto"; "tofu", beancurds; and "miso", bean paste; the pea-nut and other peas and beans. It has often been reported that the soy-bean is far superior as edible source of vegetable protein to the peanut and the azuki bean. R. Hirohata and O. Kamizawa[36] found and confirmed long ago in their experiments on rats that peanut protein is low in its nutritive value. We have later studied, for comparison the biological value of 8 kinds of legumes eaten in large quantities by the Japanese. J. Onishi[37] and M. Fujii[38], who estimated the biological value of a variety of legumes by Barnes' method[22,23] and who reached the results shown below, found that in its biological value the soy-bean was the most valuable of the 8 kinds of legumes examined and a little better than rice.

Mucuna capitata Sw. grows in the tropics and yields large toxic beans. The toxic principle was confirmed as dihydroxyphenylalanine by T. Yoshida[39] (present name Ta-cheng Tung) in our laboratory. According to Ikenaga and R. Hirohata[40], the

Tab. 26. The biological value of legume protein (%).

Protein from	Comparative nutritive value		Biological value		
	For growth	For maintenance	Biological value	Parts participating in growth	Parts Participating in maintenace
Whole egg	100	100	99	77	23
Phaseol. mungo	33	66	38	31	69
〃 radiatus	37	35	27	45	55
Dolichos lablab	25	58	34	22	78
Vigna catjang	37	68	39	33	67
Arachis hypog.	27	63	36	23	77
Pisum sativum	27	31	24	36	64
Vicia faba	41	42	28	41	59
Glycine hispida	56	62	43	63	37

detoxicated meal prepared by Hirohata's method[41] contains some 31% crude protein, and is composed of some 20% albumin, 2.3% globulin, 1.2% glutelin and 0.6 % prolamine. It was demonstrated to constitute an excellent material for "miso", soy, biscuits and bean jam. The nutritive value of the meal was studied on rats and found to be neither high nor low as a legume protein.

2. Soy-bean

The above experimental investigation disclosed that the cheapest protein of a relatively good quality is obtainable from the soy-bean.

The soy-bean has been cultivated since the Nara period (1369–1442) in Japan to become later an important protein source next to rice. Many valuable Japanese foods, such as "miso" (bean-paste), soy, "tofu" (bean-curd), "yuba" (bean curd skin), "ajinomoto" (a seasoning powder, sodium glutamate), amino acids soy, "harusame" (bean vermicelli), many kinds of cake, etc. are prepared from the soy-bean. In recent years some 4–500,000 t of this legume are produced in Japan and some 1,000,000–1,100,000 t imported.

In our animal experiments the soy-bean protein was used not in its original state as has generally been the case, but in its isolated form, because it was likely to be better absorbed in the latter than in the former state.

a. Absorption rate of soy-bean protein.

The absorption rate of soy-bean protein was examined first in rats by Y. Okuda *et al.*[42] by feeding the animals with whole soy-beans, defatted soy-bean meal, both boiled, and isolated soy-bean proteins; the real absorption rate was determined in their experiments by reducing the metabolic N from the fecal N excreted daily. The metabolic N in rats was 26.9 ± 1.48 mg per day, according to Y. Okuda.[43]

As the rat is not apparently a suitable animal for our purpose, the isolated soy-

Tab. 27. Absorption rate of soy-bean protein in rats (%, M±δ)

Boiled soy-bean	96.46±0.94 (6 rats)
Boiled soy-bean meal	96.61±2.24 (6 rats)
Isolated soy-bean protein	97.31±1.97 (6 rats)

bean protein was administered, together with rice, to 6 humans for two days and the average real absorption rate of the protein was determined by reducing the metabolic N of the Japanese[10] and unabsorbed proportion of rice N (Tab. 11 in Rep. 1) from the fecal N excreted daily by a man.

Table 28 shows the result reached and for comparison the absorbability of the soy-bean protein given in its natural, though boiled, form and in its fermented form i.e. as "natto".

Tab. 28. Real absorption rate of soy-bean protein in humans (%, M±δ)

Protein in soy-bean boiled	71.44±0.74
Protein in "natto"	81.0 ±1.95
Isolated protein	96.35±3.47

From this table it is evident that the soy-bean protein is far more easily absorbable in its isolated form than in its natural form as boiled beans or in the form of "natto".

The isolated soy-bean protein we used was obtained from defatted soy-bean meal which averaged 54% in its protein content. The meal was treated first with water, subsequently next with dilute alkali for extraction, acidified with dilute HCl (pH 4.5), boiled for 5 minutes to decompose its toxic content in it and to coagulate the dissolved protein. The yield of the protein from the meal was about 40%. It contained 16.37% N and 2.42% ash on the average.

b. Amino acid composition of soy-bean protein.

The amino acid composition was determined by S. Kimura[11] and Y. Okuda[44] by

Tab. 29. Amino acid composition of isolated soy-bean protein.

	a	b	c	d		a	b	c	d
Asp	13.95	11.98	11.56	11.60	Ileu	6.22	5.42	4.50	5.46
Thr	5.68	3.27	2.47	5.08	Leu	7.57	7.82	8.30	9.79
Ser	5.50	4.50	4.32	6.79	Tyr	3.91	4.48	3.30	3.64
Glu	19.27	19.84	20.63	23.37	Phe	4.15	6.53	4.78	6.99
Pro	4.37	4.48	5.10	7.18	His	2.57	1.67	2.73	2.40
Gly	4.78	3.31	3.96	4.86	Lys	5.99	5.43	6.09	6.32
Ala	4.96	4.10	3.79	4.67	Arg	7.37	6.77	7.68	6.87
Cys	0.80, 1.33[49]			1.51	Try	1.22	1.51	1.53	1.55
Val	5.30	4.12	4.20	5.14	NH_3	2.52	5.44	4.62	4.24
Met	1.53	1.96		1.07*	Total	106.68			118.53

The hydrolysis conditions for ordinary amino acids were as follows:

a. 24 and 72 hours with 6 N-HCl at 100° (S. Kimura[11])
b. 8 hours with 6 N-HCl at 120°, 2Kg/cm² (Y. Okuda[44])
c. 8 hours with 20% HCl at 120°, 2Kg/cm² (Y. Okuda[44])
d. 24 and 72 hours with 20% HCl at 100° (Y. Okuda[44])

* Cys was estimated by the method of Kuratomi *et al*[18]., total S by Micro-Carius' method and Met was calculaed from both content.

Moore and Stein's and other methods described in the chapter on rice protein (p. 2~3 of this volume). The quantity in mg of the essential amino acids in 1 g of N was calculated. The first limiting amino acid was conspicuously S amino acid, but the second and third were somewhat obscure.

c. The nutritive value of soy-bean protein fortified with amino acid

A. Murakami[45] and Y. Okuda[46] carried out a series of feeding experiments on more than 850 rats by keeping those on soy-bean protein in order to elucidate the needed amino acids to be added to it both qualitatively and quantitatively. Ordinarily L-enantiomer of leucine, lysine, tryptophan, phenylalanine and histidine was added, and methionine and valine in DL-form respeptively. The food containing the protein and amino acids was further added with rape-seed oil (5%), McCollum salt mixture (4%), a vitamin mixture (1%) and a sufficient quantity of dextrins to make the whole food amount to 100 g. Their animal experiments consisted of two parts: A and B. Experiment A (5th-22nd) was carried out for several groups of young rats, half male and half female, weighing from 30 to 40 g, and born on the same day, except in a few cases where these conditions were not fully satisfiable. Besides, the same uterine rats were assigned as equally as possible to the different groups of one and the same experiment. The feeding lasted for 3 or about 9 weeks and the body weight of each rat was weighed once a week.

Experiment B (23rd-28th) was made for groups of 5 or 6 male Wister rats about 100 g in weight. The animals were fed on a casein diet (20%) during the first week and on soy-bean protein during the following 3 weeks. The growth rate was measured at frequent intervals, and the weight, moisture, total N, fat and xanthine oxidase activity (XOA) (in the homogenate, according to Litwack) of the liver were determined at the end of the 4th week when the animals were sacrificed for the pur-

Tab. 30. The 5th Experiment (Aug. 10–31, 1958).

Group	Rat		Body weight (M±δ, g)			Soy-b. protein (%)	Amino acid added (%)						
	♂	♀	Initial	Final	Increase/w		Met	Val	Try	Phe	Lys	His	Leu
a	3	3	33.1	72.2	13.6±2.1	15	0.585	0.15	0.12	0.33	0.45	0.06	0
b	4	2	27.4	65.4	12.7±1.2	〃	〃	0	0	0.15	0	0	0
c	3	3	30.1	66.0	12.0±1.9	〃	〃	0	0	0	0	0	0.15
d	4	2	29.8	63.4	11.2±0.8	〃	〃	0	0	0	0	0.06	0
e	4	2	34.0	67.4	11.1±1.1	〃	〃	0.30	0	0	0	0	0
f	3	3	34.2	67.6	10.6±1.3	〃	〃	0	0.075	0	0.45	0	0
g	4	2	29.6	61.7	10.7±1.5	〃	〃	0	〃	0.15	〃	0	0
h	4	2	27.9	58.2	10.1±1.2	〃	〃	0	0	0	〃	0	0
i	4	2	28.7	58.8	10.1±2.7	〃	〃	0	0.12	0	0	0	0
j	3	3	32.5	44.3	3.9±1.3	〃	0	0	0	0	0	0	0
k	3	2	39.3	37.0	−0.7	10	0	0	0	0	0	0	0

pose. The allantoin-urea ratio of the urine was also measured for some of the groups at the end of each week of the feeding.

The food given in Experiment A and B was quite the same in its chemical composition except that 2.5 mg of sodium molybdate was added to 1 kg of McCollum salt mixture in Experiment B and not in Experiment A.

Some of the data obtained will be shown in the following tables:

Tab. 31. The 7th Experiment (Sept. 15–Oct. 5, 1958).

Group	Rat		Body weight (M±δ, g)			15% Protein of	Amino acid added (%)		
	♂	♀	Initial	Final	Increase/w.		Met	Phe	Leu
a	3	2	29. 1	89. 4	20. 1±2. 9	Soy-bean	0. 585	0. 15	0
b	2	3	28. 6	86. 9	19. 4±4. 8	Skim-milk	0	0	0
c	2	3	30. 5	87. 4	19. 2±4. 8	Soy-bean	0. 585	0	0. 15
d	2	3	28. 9	77. 4	16. 2±2. 8	〃	〃	0	0

Tab. 32. The 8th Experiment (Oct. 3–24, 1958).

Group	Rat		Body weight (M±δ, g)			Soy-bean protein (%)	Amino acid added (%)	
	♂	♀	Initial	Final	Increase/w.		DL-Met	L-Met
a	3	2	40. 9	73. 2	10. 8±1. 6	15	1. 17	0
b	2	3	37. 6	68. 1	10. 2±1. 2	〃	0. 585	0
c	2	3	40. 7	70. 7	10. 0±2. 0	〃	0	0. 585

Tab. 33. The 12th Experiment (Mar. 8–29, 1959).

Group	Rat		Body weight (M±δ, g)			10% Protein of	Amino acid added (%)		
	♂	♀	Initial	Final	Increase/w.		Met	Leu	Phe
a	3	2	38. 1	107. 3	23. 1±3. 4	Soy-bean	0. 8	0. 1	0
b	2	3	35. 3	103. 6	22. 8±2. 5	〃	〃	0. 2	0
c	3	2	37. 0	104. 9	22. 6±2. 5	〃	〃	〃	0. 10
d	2	3	39. 1	103. 3	21. 4±5. 2	〃	0. 4	0. 1	0
e	2	3	37. 2	99. 9	20. 9±1. 82	〃	0. 4	0	0
f	2	3	36. 5	98. 2	20. 6±4. 9	〃	0. 8	0	0
g	2	3	38. 5	97. 9	19. 8±0. 62	〃	0. 4	0. 1	0. 1
h	2	3	35. 0	94. 1	19. 7±1. 4	Skim-milk	0	0	0

Tab. 34. The 13th Experiment (Apr. 19-May 10, 1959).

Group	Rat		Body weight (M±δ, g)			10% Protein of	Amino acid added (%)			
	♂	♀	Initial	Final	Increase/w.		Met	Leu	Lys	Thr
a	2	3	43. 0	124. 0	27. 0±4. 6	Soy-bean	0. 4	0. 3	0. 2	0. 2
b	2	3	42. 3	116. 5	24. 7±3. 4	〃	〃	0. 4	0	0
c	2	3	43. 8	117. 2	24. 5±2. 8	〃	0. 8	0. 2	0	0
d	2	3	41. 3	112. 7	23. 8±3. 4	〃	0. 4	0. 1	0	0
e	2	3	43. 8	112. 2	22. 8±3. 1	〃	〃	0. 3	0	0
f	2	3	41. 9	109. 6	22. 6±2. 4	〃	0. 8	0. 3	0	0
g	2	3	42. 9	110. 4	22. 5±2. 9	〃	0. 4	0. 2	0	0
h	2	3	43. 8	109. 7	22. 0±2. 7	〃	0. 8	0. 4	0	0
i	2	3	42. 2	98. 9	18. 9±3. 5	Skim-milk	0	0	0	0

Tab. 35. The 14th Experiment with 10% soy-bean protein (Jun. 9–30, 1959).

Group	Rat		Body weight (M±δ, g)			Amino acid added (%)	
	♂	♀	Initial	Final	Increase/w.	DL-Met	L-Leu
a	6	4	39. 3	89. 8	16. 8±1. 6	0. 4	0. 2
b	6	4	39. 3	88. 3	16. 3±1. 8	0. 4	0. 4
c	6	4	39. 4	88. 0	16. 2±1. 8	0. 4	0. 3
d	6	4	39. 2	86. 4	15. 8±0. 37	0. 4	0. 1
e	6	4	39. 2	85. 6	15. 4±2. 3	0. 8	0. 2

Tab. 36. The 15th Experiment with 10% soy-bean protein (Jun. 15-Jul. 6, 1959).

Group	Rat		Body weight (M±δ, g)			Amino acid added (%)				
	♂	♀	Initial	Final	Increase/w.	Met	Leu	Thr	Phe	Lys
a	3	2	41. 8	99. 7	19. 3±1. 0	0. 4	0. 1	0. 2	0	0
b	3	2	41. 3	94. 2	17. 6±3. 2	0. 4	0. 1	0	0. 2	0
c	3	2	41. 5	93. 4	17. 3±2. 0	0. 4	0. 1	0	0	0
d	3	2	41. 2	92. 2	17. 0±2. 2	0. 4	0. 1	0	0	0. 2

Tab. 37. The 23rd Experiment with 10% soy-bean protein food (Jul. 19-Aug. 8, 1960).

Group	Rat	Body weight (M±δ, g)			Liver					Met added (%)
	♂	Initial	Final	Increase /w.	Weight (g)	Moisture (%)	Total-N (%)	Fat (%)	XOA(O_2 μl/h/g)	
a	5	91. 3 ± 6. 6	143. 8 ± 14. 0	18. 0 ± 3. 5	6. 04 ± 0. 54	65. 32 ± 2. 39	10. 01 ± 0. 73	28. 18 ± 5. 67	48. 0 ± 30. 7	0. 4
b	5	91. 2 ± 7. 4	129. 6 ± 15. 9	13. 2 ± 4. 2	5. 66 ± 0. 75	67. 23 ± 1. 94	10. 08 ± 0. 74	33. 91 ± 3. 86	103. 9 ± 41. 8	0. 6
c	5	90. 7 ± 6. 8	131. 2 ± 20. 0	13. 9 ± 4. 7	6. 10 ± 0. 69	63. 57 ± 1. 07	10. 34 ± 0. 88	41. 85 ± 3. 75	63. 5 ± 31. 1	0. 8
d	5	91. 5 ± 6. 7	134. 3 ± 9. 3	14. 6 ± 1. 5	6. 23 ± 0. 76	67. 15 ± 3. 19	11. 99 ± 0. 18	11. 99 ± 0. 18	52. 2 ± 29. 6	1. 0

Tab. 38. The 24th Experiment with 10% soy-bean protein food (Aug. 12–31, 1960).

Group	Rat	Body weight (M±δ, g)			Liver					Amino acid added (%)		
	♂	Initial	Final	Increase /w.	Weight (g)	Moisture (%)	Total-N (%)	Fat (%)	XOA (O_2 μl/h/g)	Met	Phe	Lys
a	5	113.9 ± 13.8	156.2 ± 19.2	14.8 ± 4.8	5.33 ± 0.68	65.86 ± 4.30	12.49 ± 0.68	29.31 ± 9.36	138.6 ± 53.3	0.6	0.1	0
b	5	111.9 ± 18.7	149.8 ± 29.2	13.3 ± 5.2	4.98 ± 1.14	71.88 ± 2.77	13.25 ± 0.50	29.90 ± 6.21	180.0 ± 97.0	0.6	0.2	0
c	5	115.5 ± 15.4	146.9 ± 24.0	11.0 ± 4.8	4.87 ± 0.62	70.64 ± 2.17	13.61 ± 0.29	30.24 ± 6.25	146.2 ± 64.2	0.6	0	0.1
d	5	113.9 ± 17.8	154.9 ± 24.0	14.4 ± 1.2	5.10 ± 0.91	69.95 ± 3.36	13.71 ± 0.38	28.77 ± 7.65	163.8 ± 125.4	0.6	0	0.2

Tab. 39. The 25th Experiment with 10% soy-bean protein food (Sept. 15-Oct. 5, 1960)

Group	Rat	Body weight (M±δ, g)			Liver					Amino acid added (%)		
	♂	Initial	Final	Increase /w.	Weight (g)	Moisture (%)	Total-N (%)	Fat (%)	XOA (O_2 μl/h/g)	Met	Leu	Thr
a	5	128.5 ± 29.5	205.9 ± 17.6	27.1 ± 3.9	7.12 ± 0.91	77.86 ± 3.35	13.59 ± 1.11	29.68 ± 7.71	191.9 ± 91.9	0.6	0.2	
b	5	128.8 ± 6.0	212.7 ± 10.9	29.4 ± 3.3	7.65 ± 0.61	77.97 ± 1.80	13.48 ± 0.47	26.99 ± 5.30	205.4 ± 37.9	〃	0.3	
c	5	127.9 ± 8.5	207.2 ± 12.4	27.8 ± 2.5	7.30 ± 0.53	77.69 ± 3.73	13.52 ± 0.56	16.73 ± 0.54	115.8 ± 55.8	〃	0	0.1
d	5	131.7 ± 12.0	223.3 ± 16.7	32.1 ± 3.8	7.83 ± 0.67	79.57 ± 1.19	11.80 ± 1.05	17.23 ± 2.38	55.6 ± 24.4	〃	0	0.2

Tab. 40. The 26th Experiment with 10% soy-bean food (Oct. 16-Nov. 6, 1960)

Group	Rat	Body weight (M±δ, g)			Liver					Amino acid added (%)				
	♂	Initial	Final	Increase /w.	Weight (g)	Moisture (%)	Total-N (%)	Fat (%)	XOA (O_2 μl/h/g)	Met	Leu	Phe	Lys	Thr
a	5	123.5 ± 4.9	179.9 ± 10.5	18.8 ± 1.8	5.79 ± 0.61	70.17 ± 2.37	12.39 ± 2.07	19.71 ± 1.75	187.1 ± 76.9	0.6	0.3	0.1	0	0
b	5	123.3 ± 7.3	189.1 ± 17.9	21.9 ± 4.1	6.47 ± 0.65	66.51 ± 8.24	12.71 ± 1.71	17.97 ± 2.45	140.5 ± 48.2	〃	〃	0	0.2	0
c	5	128.7 ± 16.2	201.2 ± 25.2	24.2 ± 3.9	7.30 ± 0.83	72.23 ± 1.22	12.66 ± 0.74	19.39 ± 3.98	140.2 ± 48.6	〃	〃	0	0	0.2

Tab. 41. The 27th Experiment with 10% soy-bean protein food (Nov. 11-Dec. 6, 1960)

Group	Rat	Body weight (M±δ, g)			Liver					Amino acid added (%)				
	♂	Initial	Final	Increase /w.	Weight (g)	Moisture (%)	Total-N (%)	Fat (%)	XOA (O_2 μl/h/g)	Met	Leu	Phe	Lys	Thr
a	6	161.6 ± 53.7	220.0 ± 45.1	20.4 ± 8.7	7.61 ± 1.26	70.75 ± 0.38	12.63 ± 0.24	11.42 ± 4.18	114.0 ± 32.9	0.6	0.3	0.1	0.2	0.2
b	6	166.3 ± 48.6	219.2 ± 48.5	18.5 ± 3.0	8.35 ± 1.45	74.48 ± 4.22	12.05 ± 0.37	19.29 ± 1.96	105.5 ± 69.0	〃	0	〃	〃	〃
c	6	161.2 ± 54.5	226.5 ± 45.4	22.0 ± 6.8	8.20 ± 1.26	79.18 ± 2.38	12.55 ± 0.60	14.66 ± 1.24	118.7 ± 21.9	〃	0.3	0	〃	〃
d	6	169.7 ± 50.0	229.7 ± 45.1	21.0 ± 7.2	8.10 ± 1.25	78.39 ± 6.48	12.73 ± 0.69	12.76 ± 1.22	136.9 ± 63.9	〃	〃	0.1	0	〃
e	6	174.1 ± 55.0	222.6 ± 31.8	17.0 ± 7.0	7.75 ± 0.67	80.21 ± 1.21	12.10 ± 0.71	13.56 ± 1.82	165.9 ± 55.3	〃	〃	〃	0.2	0

Though the result of Experiment A and B lead to no clear-cut conclusion, it seems evident at methionine in a concentration of 0.6 to 0.8% is indispensable as a substance to be added to 10% soy-bean protein diet and that a greater dietetic benifit will be gained by a further addition to it of L-leucine (0.2–0.3%), L-phenylalanine (0.1–0.2%), DL-threonine (0.1–0.2%) and L-lysine (0.1–0.2%).

The soy-bean protein so enriched with various amino acids was fed to some human babies in the weaning or post-weaning period by S. Asano and I. Asano[47] of our medical school, and by N. Goya and S. Ezaki[48] of the Kyushu University Medical School, each group in the pediatrical department of their medical school. It was given to the babies as substitute for half the quantity of the animal protein on which they had hitherto been fed, such as milk or eggs.

The results obtained are shown in Table 42.

The effect of the fortified soy-bean protein on adult humans before and after the

Tab. 42. The effect of the enriched soy-bean protein on the human baby in the weaning or post-weaning period.

No.	Name	Sex		Age in days	Initial body weight (g)	Days of feedinng	Increase of body weight /day (g)	Rbc (10^6)	Hb (%)	Serum protein (%)	Amino acid added (in % to soy-bean protein)
1	D. H.	♂	I II	247	10, 320	11	20 27	5. 08 4. 81	105 120	6. 6 6. 3	DL-Met (4), L-Leu (7) L-Phe (2), L-Glu (3)
2	N. H.	♂	I II	245	8, 670	11	25 18	5. 22 4. 69	95 97	6. 6 7. 8	〃
3	K. N.	♂	I II	241	7, 100	11	18 18	5. 11 5. 50	106 100	6. 7 6. 7	〃
4	K. Y.	♂	I II	16 months	10, 090	21	5. 4 9. 0	4. 31 4. 80	66 70	8. 4 8. 2	〃
5	T. G.	♂	I II	14 months	8, 590	21	15 7. 6	4. 06 4. 18	67 70	8. 2 8. 1	〃
6	H. A.	♂	I II	15 months	9, 430	21	5 4. 9	4. 76 4. 65	70 70	8. 0 8. 1	〃
7	T. S.	♂	I II	199	6. 600	23	15. 5 16. 5	4. 64 4. 34	70 70	7. 2 7. 3	〃
8	H. K.	♂	I II	331	7, 080	21	30 30	4. 86 4. 04	80 90	6. 8 6. 8	DL-Met (4), L-Leu (1) L-Glu (0. 5)
9	A. I.	♂	I II	10 months	8, 800	45	19. 3 25	4. 93 5. 30	83 90	 7. 8	DL-Met (6), L-Leu (3) L-Lys (3), DL-Thr (2. 2)
10	E. H.	♂	I II	317	9, 500	19	12. 5 15	5. 23 5. 11	105 100		〃

I: Period of feeding of ordinary diet

II: Period of feeding of soy-bean protein; half the amount of the animal protein in the ordinary diet was substituted with an equal quantity of soy-bean protein enriched with amino acids.

surgical operation they underwent, is under investigation.

Summary to the studies on legumes.

1. On the protein contents of the 8 kinds of pulses and their preparations examined that of "natto", a soy-bean preparation, was found most easily absorbable, followed by soy-bean itself, and this by the peanut.

2. The protein content of mungbean malt was better absorbable than that of the mung-bean itself.

3. The isolated protein of soy-bean is most easily absorbable in humans among the legume proteins in original state examined and somewhat better absorbable than animal protein.

4. In biological value soy-bean protein headed the list, followed in descending order by mung-bean protein, azuki, and peanut protein.

5. Of the 8 different legumes examined the soy-bean proved to be a source of the cheapest and most plentiful protein of the best quality.

6. Our feeding experiments on rats disclosed that soy-bean protein fortified by the addition to it of 6–8% DL-methionine, 1–3% L-leucine, 1% L-phenylalanine or DL-threonine is about as nutritive as, or a little more so than, milk protein; the animals fed on the fortified soy-bean went on growing while those fed on unfortified soy-bean protein showed no growth.

7. The human babies given the fortified soy-bean protein for a certain period as substitute for half the amount of animal protein contained in their ordinary diet showed that their growth rate and other aspect of their physical development were nearly the same in this and in any other period.

REFERENCES 3

34. Onishi, I. : *Fukuoka Acta Medica* **44**: 54, 1953
35. Fujii, M. : *ibid.* **44**: 374, 1953
36. Hirohata, R. and Kamizawa, O. : *J. Form. Med. Assoc.* **33**: 1094, 1934
37. Onishi, I. : *Fukuoka Acta Medica* **44**: 731, 1953
38. Fujii, M. : *ibid.* **44**: 787, 1953
39. Yoshida, T. : *Tohoku J. exp. Med.* **48**: 27, 1944
40. Ikenaga, S., Ikenaga, M. and Hirohata, R. : *Nutrition and Food* (Japan) **4**, 59, 1951
41. Hirohata, R. to be published
42. Okuda, Y., Sakka, A. and Tominaga, S. : *Fukuoka Acta Medica* **52**: 52, 1961
43. Okuda, Y. to be published
44. Okuda, Y. to be published
45. Murakami, A. *Yamaguchi Igaku.* **9** : 1325, 1960; **10**: 565, 1961
46. Okuda, Y. to be published
47. Asano, S. and Asano, I. to be published
48. Goya, N. and Ezaki, S. to be published
49. Nagase, T. : *Fukuoka Acta Medica,* **48**: 1828, 1957