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Plant Proteins. IV.—The Biological Values of Soyabeans, Linseedmeal and Soyabeans Supplemented by Cystine.

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THE present investigation constitutes a continuation of our studies on the nutritive value of our most commonly utilized plant proteins. Linseedmeal is a popular feed for nearly every type of farm animal and consequently is extensively used in this country. Soyabeans are less popular, but due to the fact that they may be grown fairly successfully under local conditions, their nutritional value in comparison with other plant protein becomes a practical necessity.

Morris and Wright (1933), in a comparison of the proteins of beans, linseed and meatmeal for milk production came to the conclusion that beans and meatmeal are better sources of protein for milk production than linseedmeal. The biological values calculated according to the formula of Perkins ranked in the following order: Beanmeal 59, meatmeal 55, and linseedmeal 46. Crichton (1932), in a fattening test of two groups of Aberdeen Angus steers on bran and linseed cake, states that the bran ration gave better gains than the linseed ration. Mitchell (1931), determined the nutritive value of linseedmeal and cottonseedmeal for growing pigs and found that, while linseedmeal was slightly more digestible than cottonseedmeal, there was no actual difference in their respective biological values; the values being 61 for linseedmeal and 63 for cottonseedmeal. Kenneth, Morrison and Maynard (1935), employing their synthetic rations developed for sheep, found in a comparison of the biological values of soyabeans, corngluten and linseedmeal, that the latter was inferior in protein to soyabeans, the respective biological values being 72·8 for soyabeans and 67·7 for linseedmeal.

Csonka (1934), from chemical analyses of various varieties of soyabeans, does not support the general conception of a quantitative deficiency of cystine in soyabeans but admits that some varieties may

be deficient in this amino acid. Hayward, Steenbock and Bohstead (1936) found, with rats, that both the Illini and Herman varieties of soyabeans were inefficient sources of protein. The addition of 0·3 per cent. l-Cystine or the application of heat practically doubled the nutritive value of the protein. The commercial preparation of soyabeanmeal apparently influenced its protein constitution markedly. Low temperature preparations at 105° C. for 2 hours or cooked at 82° C. for 90 minutes left the protein unchanged and similar in nutritive value to the raw product. Cooking at 105° C. to 121° C. for 90 minutes changed the protein to such an extent that it became double the nutritive value of the raw meal. Plimmer and Rosedale (1934), in an extensive investigation of the relative values of different proteins, as determined by the growth method on chickens, found that soyabeans were superior in protein to linseedmeal but inferior as compared to fishmeal and meatmeal. Schmidt (1934), in a determination of the nitrogen retention of yeast, soyabeans and peanutmeal in pigs, found that the nitrogen retention per head was 13·69 gm. for yeast, 13·22 gm. for peanutmeal, and 13·22 gm. for soyabeans.

In accordance with the general belief that soyabeans are deficient in cystine, this amino acid was incorporated in a ration of soyabeans and the biological value determined. Until quite recently cystine was thought to be an indispensable amino acid. Rose (1937), however claims that this is not the case and that methionine is the indispensable sulphur amino acid, while cystine only acts as a stimulant to growth when methionine is present in sub-optimal quantities. Weichselbaum (1935), on the other hand, finds that on a cystine deficient ration rats develop a specific syndrome, which can be prevented by both cystine and methionine, but that only the former amino acid can rectify conditions once symptoms have appeared.

Experimental.

The biological value of each protein, except for linseedmeal, was determined on six individual rates. Due to the scarcity of rats an unavoidable change in the general routine of our metabolism work was brought about. Instead of running the usual nitrogen low and protein periods on six rats and then discarding them, the rats under the present conditions were employed for two successive periods of protein feeding and one nitrogen low period to serve for both protein periods. In our experience this deviation does not constitute a serious source of error, since the endogenous nitrogen of rats over a period of a month does not vary to any appreciable extent, especially if they are kept on a standard ration of 10 per cent. protein before the endogenous nitrogen is determined. The rations were compounded to approximate 9 per cent. of protein and to contain all the other essential ingredients for normal growth. The protein feeds investigated were put through a mill and ground into a fine state in order to facilitate homogeneous mixing. The cystine incorporated in the rations was prepared from wool. The percentage composition of the rations are given in Table 1.

TABLE 1.

Composition of Rations on Percentage Basis.

Ingredients.	N–low Ration.	Soyabean Ration.	Linseed Ration.	Soyabean and Cystine Ration.
Soyabeans	—	35·2	—	34·7
Linseed meal	—	—	26·1	—
Cystine	—	—	—	·20
Ether Ext. Egg White	3·8	—	—	—
Sucrose	10·0	10·0	10·0	10·0
Yeast Ext.(1)	10·0	10·0	10·0	10·0
Butterfat	8·0	8·0	8·0	8·0
Codliveroil	2·0	2·0	2·0	2·0
Salt Mixture(2)	4·5	4·5	4·5	4·5
Agar	2·0	2·0	2·0	2·0
Starch	58·7	27·3	38·4	29·6
NaCl	1·0	1·0	1·0	1·0
TOTAL	100·0	100·0	100·0	100·0
Per cent. Nitrogen	·659	1·51	1·50	1·46

(1) Yeast extract was prepared according to the method of Itter, S., Orent, E. R., and McCollum, E. V., 1935. *J. Biol. Chem.*, Vol. 108, No. 2, pp. 571-577.

(2) A modified Osborne and Mendel salt mixture described by Hawk, P. B., and Osler, B. L., 1931. *Science*, Vol. 74, p. 369.

The nitrogen metabolism data as well as the calculation of the biological values are presented in Table 2.

From these figures it will be seen that the protein of raw soyabeans is of an inferior quality. In fact, it exhibits the lowest biological value of all the plant proteins so far investigated. The individual biological values vary from 50 to 62 with an average value of 55. The apparent and true digestibilities are lower than those of other plant proteins, except lucerne, and average 62 and 81 per cent. respectively. It is fairly obvious that the low digestibility is not the primary cause of its poor nutritive value, since when soyabeans are supplemented by ·20 per cent. cystine the apparent and true digestibility remain practically unaltered, whereas the biological value of the supplemented soyabean protein is increased significantly. Such a decided increase in the biological value definitely signifies a supplementary effect of cystine on soyabeans, and can only be interpreted on the grounds that a deficiency of this amino acid in the protein molecule of soyabeans seriously impairs and diminishes the utilization of its nitrogen. The result is somewhat opposed to the new theory of the dispensability of cystine as recently postulated by Rose (1937). According to Rose methionine may be present in suboptimal quantities in soyabeans and the addition of 0·2 per cent. cystine simply as a stimulant to growth. This argument, it seems, does not fully explain the metabolism data presented in this paper. If cysine is

dispensable one would hardly expect that its inclusion in such small small quantities would increase the utilization of soyabean nitrogen for the composite needs of maintenance and growth as is clearly demonstrated by our data. In fact one would expect the addition of an amino acid dispensable for tissue synthesis to decrease the biological value instead of enhancing it, since such an amino acid will be added to the fraction of incomplete assortment of amino acids and deaminized with no actual use for the body. The indispensability of cystine in soyabeans which might contain methionine in suboptimal quantities is further supported by data obtained from paired feeding tests, to be published shortly, in which soyabeans supplemented by cystine are superior to soyabeans alone.

From the biological value of linseedmeal as calculated in Table 2 it is apparent that its almost universal use in stock feeding is not only based on its popularity and palatability but to a large degree on the high quality of its protein. The individual biological values vary from 74 to 82, with an average of 78. Its apparent and true digestibility, as shown in Table 3, are of the same magnitude as those of most other plant proteins; the respective values being 75 and 98 per cent. This would indicate that the higher biological value of linseedmeal in comparison with peanutmeal, sesamemeal, and coprameal as determined in a previous paper [Smuts and Malan (1937)] is due to a better constituted protein molecule in respect to the indispensable amino acids.

TABLE 3.

Summary of Apparent and True Digestibilities.

Rat No.	Soyabean.		Rat No.	Soyabean and Cystine.		Linseed.	
	Apparent.	True.		Apparent.	True.	Apparent.	True.
1	64	81	7	57	76	75	94
2	60	79	8	64	86	74	96
3	62	81	9	67	93	75	100
4	69	88	10	69	88	76	94
5	60	79	11	57	79	75	97
6	59	78	12	66	85	73	91
Average.	62	81		63	84	75	95

SUMMARY AND CONCLUSIONS.

By means of the nitrogen balance-sheet method a biological value of 55 for soyabeans and 78 for linseedmeal at approximately 8 per cent. level has been obtained. Utilizing the same method and substituting an equivalent amount of soyabean nitrogen by ·20 per cent. cystine it was found that cystine supplemented soyabean protein effectively and increased the utilization of its nitrogen by 19 per cent.

TABLE 2.

Metabolism Data and Calculation of

Rat No.	Initial Weight.	Final Weight.	Average Weight.	Daily Food Intake.	Daily N Intake.	Daily N in Feces.	Body N in Feces.	
							Per gram Food.	Per Day.
	Gm.	Gm.	Gm.	Gm.	Mgm.	Mgm.	Mgm.	Mgm.
								N LOW PERIOI
1.....	114	111	113	7·1	—	18·0	2·54	—
2.....	107	101	104	6·2	—	17·7	2·85	—
3.....	104	110	107	7·7	—	19·6	2·55	—
4.....	111	110	111	6·8	—	19·6	2·88	—
5.....	105	100	103	6·8	—	20·3	2·99	—
6.....	97	95	96	6·0	—	18·0	2·00	—
								SOYABEAN PERIOD
1.....	95	97	96	7·9	119·3	43·0	2·54	20·1
2.....	95	97	96	8·1	122·3	48·6	2·85	23·1
3.....	92	92	92	8·1	122·3	46·0	2·55	20·7
4.....	92	92	92	7·0	105·7	32·4	2·88	20·2
5.....	90	90	90	8·0	120·8	48·0	2·99	23·9
6.....	87	82	85	6·9	10·42	43·2	3·00	20·7
								N LOW PERIOD FOR SOYABEANS PLUS 0·2
7.....	91	95	93	7·3	—	21·0	2·88	—
8.....	96	95	96	6·0	—	19·3	3·22	—
9.....	95	92	94	6·8	—	25·7	3·78	—
10.....	96	99	98	7·3	—	19·6	2·68	—
11.....	106	100	103	7·2	—	23·7	3·29	—
12.....	97	97	97	6·5	—	18·2	2·80	—
								SOYABEANS PLUS 0·2 PER CENT. CYSTINE PE
7.....	87	92	90	8·0	116·8	50·8	2·88	23·0
8.....	90	97	94	7·7	112·4	40·4	3·22	24·8
9.....	90	97	94	8·0	116·8	38·0	3·78	30·2
10.....	92	97	95	8·0	116·8	36·0	2·68	21·4
11.....	97	100	99	8·0	116·8	50·4	3·29	26·3
12.....	82	93	88	8·0	11·68	39·6	2·80	22·4
								LINSEED MEAL PERIOD CONTAI
7.....	80	88	84	8·1	121·5	30·6	2·88	23·2
8.....	85	95	90	8·1	121·5	31·4	2·22	26·1
9.....	85	99	92	8·1	121·5	30·0	3·78	30·6
10.....	86	92	89	7·7	115·5	28·2	2·68	20·6
11.....	89	95	92	8·1	121·5	30·0	3·29	26·6

TABLE 2.

nd Calculation of Biological Values.

Food N in Feces.	Absorbed N.	Daily N in Urine.	Body N in Urine.		Food N in Urine.	Retained N.	Biol. Value.	True Digest.	Approx. Digest.
			Per 100 Gm. wt.	Per Day.					
Mgm.	Mgm.	Mgm.	Mgm.	Mgm.	Mgm.				
OD FOR SOYABEANS.									
—	—	18·8	16·6	—	—	—	—	—	—
—	—	18·8	18·1	—	—	—	—	—	—
—	—	19·8	18·5	—	—	—	—	—	—
—	—	19·8	17·8	—	—	—	—	—	—
—	—	20·3	19·7	—	—	—	—	—	—
—	—	17·9	18·6	—	—	—	—	—	—
D 1·51 PER CENT. N.									
22·9	96·4	56·4	16·6	15·9	40·5	55·9	58	81	64
25·5	9·68	61·6	18·1	17·4	44·2	52·6	54	79	60
25·3	97·0	61·6	18·5	17·0	44·6	52·4	54	79	62
12·2	93·5	60·4	17·8	16·4	44·0	49·5	53	88	69
24·1	96·7	54·8	19·7	17·7	37·1	59·6	62	80	60
22·5	81·7	56·4	18·6	15·8	40·6	41·1	50	78	59
						Average	55	81	62
·2 PER CENT. CYSTINE AND LINSEED RATION.									
—	—	18·7	20·1	—	—	—	—	—	—
—	—	20·1	20·9	—	—	—	—	—	—
—	—	27·5	29·3	—	—	—	—	—	—
—	—	22·4	22·9	—	—	—	—	—	—
—	—	23·3	22·6	—	—	—	—	—	—
—	—	2·15	22·2	—	—	—	—	—	—
'ERIOD. CONTAINING 1·46 PER CENT. NITROGEN.									
27·8	89·0	30·0	20·1	18·1	11·9	77·1	87	76	57
15·6	96·8	44·0	20·9	19·6	24·4	72·4	75	86	64
7·8	109·0	54·8	29·3	27·5	27·3	81·7	75	93	67
14·6	10·22	50·4	22·9	21·8	28·6	73·6	72	88	69
34·1	92·7	53·6	22·6	22·4	31·2	61·5	66	79	57
17·2	99·6	48·4	22·2	19·5	28·9	70·7	71	85	66
						Average	74	85	63
AINING 1·50 PER CENT. NITROGEN.									
7·3	114·2	37·6	20·1	16·9	20·7	93·5	82	94	75
5·3	116·2	46·0	20·9	18·8	27·2	89·0	77	96	73
0·6	121·5	48·8	29·3	27·0	21·8	99·7	82	100	75
7·6	107·9	49·8	22·9	20·4	29·4	78·5	73	93	76
3·4	11·81	52·0	22·6	20·8	31·2	86·9	74	97	75
						Average	78	98	75

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