

THE DIGESTIBILITY OF SOY BEAN MEAL BY MAN.*

By J. F. LYMAN and W. G. BOWERS,

There always has been considerable interest, in connection with human nutrition, in the seeds of the legumes. The common white or navy bean has played a prominent part in the affairs of the United States in supplying nourishment to soldiers in the service and to laborers on the farm and in the factory. The bean has been recommended as the "poor man's beefsteak," supplying as does meat, large quantities of proteins.

In China and Japan another legume, the soy bean, is extensively used as human food. This is ordinarily prepared for the table by processes not in general use in this country, usually involving some kind of fermentation. These preparations supply a very important part of the food requirement, especially of the protein requirement, of the Chinese and Japanese, and have been found to be well utilized in the body, in some cases 96 per cent of the protein being absorbed.¹

The soy bean has been cultivated rather extensively in the United States in recent years, but it has been used almost entirely as forage or for animal feed. Recently a soy bean meal, a by-product in the manufacture of soy bean oil, has been produced in considerable amounts in some sections of the South. The composition of this material and of the whole beans in comparison with common white beans suggests that we have here valuable supplies of human food which should not be neglected. The following table gives the average composition of the different materials.

	Moisture Percent	Protein Percent	Fat Percent	Fiber Percent	N-free Extract Percent	Ash Percent
² White beans (dry)...	12.6	22.5	1.8	4.4	55.2	3.5
³ Soy beans.....	10.0	38.29	14.89	4.64	26.64	5.54
Soy bean meal.....	5.7	46.66	5.1	5.5	32.3	5.75

Obviously, chemical analyses alone do not measure the nutritive value of food. We must know also the digestibility of the food, the relative quality of its proteins, carbohydrates, fats and minerals, the extent to which accessory substances or vitamins occur, and finally whether, for any reason, it exerts a harmful influence on the body.

*From the Laboratory of Agricultural Chemistry and Soils, The Ohio State University, Columbus.

Mendel and Fine⁴ found the protein in mush prepared from soy beans to be from 74.5 to 87.6 per cent digestible by dogs and 85.3 per cent digestible by men (uncorrected values). In fact the protein of soy beans was only 2.6 per cent less digestible than was the protein in a mixed diet of wheat, meat, eggs and peanut butter. The protein of the common white bean, baked in the usual way, was distinctly less digestible, viz., 77.9 per cent, in the human subject. The experiments of Wait⁵ on the digestibility of white beans agree with this result. Daniels and Nichols,⁶ from experiments on rats, have concluded that the proteins of the soy bean are highly efficient in promoting the growth of young animals, in fact, about as efficient as casein of milk. On the other hand, the proteins of the white bean appear to be decidedly poorer in quality or about as valuable as the proteins of corn.⁷ Osborne and Mendel⁸ found in soy beans abundant amounts of water-soluble accessory or vitamine, while the fat-soluble vitamine, though not abundant, appears to exceed the amount found in other seeds and grains commonly used for human food.

The nutritive quality of the white bean is further lowered by the presence of considerable amounts of carbohydrates, *e. g.*, hemicelluloses, which are indigestible in man, and which ferment in the intestine with the production of large quantities of gas, resulting in discomfort and even in injury to the intestine because of the stretching effect of the gas.⁷ The carbohydrates of the soy bean, while resembling those of the white bean, appear to be considerably more digestible and less prone to intestinal fermentation. Mendel and Fine⁴ in comparable experiments with dogs, fed in one case soy bean flour and in the other a preparation made from hulled white beans, and found five times as much fiber and over three times as much hemicellulose in the feces of the white bean fed animal. In the human subject the weight of the air dry feces from the soy bean feeding was increased only four per cent above the mixed diet period, while on the white bean diet the increase in weight of air dry feces was 68 per cent, indicating a good utilization of the non-nitrogenous material in the first case and a poor utilization in the second. In our own experiments the liberal use of soy bean meal in the diet, 120 grams per day for a three-day period, did not result in voluminous stools, on the contrary, both the protein and carbohydrates (N-free extract) of the soy bean meal was highly digestible, as will appear from the following experiment.

EXPERIMENT I.

The subject was a healthy man, aged 38, weight 150 pounds, engaged in moderately active laboratory work each day. Since, obviously, it is impossible to consume with relish an exclusive diet of soy bean meal, a mixed diet was selected containing a few articles of known digestibility in addition to soy bean meal, the chief constituent. The feces from the three-day experimental period were marked off with lampblack taken with the appropriate meals. Soon after collection of the stools they were moistened with alcohol containing a little sulphuric acid, dried on the steam bath, brought to an air-dry condition by exposure to the atmosphere of the laboratory and finely ground. Protein was determined by the Kjeldahl method ($N \times 6.25$); fat by the method of Gephart and Csonka,⁹ nitrogen-free extract, fiber and ash by the ordinary routine methods.¹⁰

The soy bean meal used in this experiment had the following composition:

Moisture.....	6.5	percent
Ash.....	5.7	"
Protein.....	44.1	"
Crude Fiber.....	5.9	"
Fat.....	3.3	"
N-free Extract.....	35.5	"

Two hundred grams of this meal were mixed with 400 grams of patent wheat flour and 10 grams of sugar and made into yeast-raised bread. This bread was of good texture and highly palatable.

The diet for the three days was as follows, approximately one-third being consumed each day.

	Grams	Protein Grams	Fat Grams	N-free Ext. Grams	Calories
Soy bean meal.....	200	88.2	6.6	71	696
Patent wheat flour.....	400	53.2	6.0	238	1420
Milk.....	3000	103.1	126.0	141	2064
Butter.....	200	.....	170.0	...	1530
Cane sugar.....	200	.....	.....	200	800
Total.....	4000	244.5	302.6	700	6510
Per Day.....	1330	81.5	100.8	233	2170

The feces from the three days weighed 248 grams moist, and 66.6 grams air-dry. They contained:

	Percent	Grams
Moisture.....	7.25	4.82
Ash.....	19.70	13.12
Protein.....	27.66	18.82
Crude fiber.....	8.46	5.63
Fat.....	22.01	14.65
N-free extract.....	15.22	10.14

In addition to undigested food residues, feces always contain nitrogenous metabolic products derived (1) from the digestive fluids and (2) from mucous and epithelial cells from the walls of the digestive tract. In order to determine the amount of these metabolic products a basal ration consisting of milk, butter, sugar, starch and agar, and designed to yield feces of about the same bulk as in the soy bean period was eaten. The diet was as follows:

3000 grams milk
275 grams butter
150 grams cane sugar
130 grams potato starch, boiled in water to make a pudding.
36 grams agar, eaten dry and raw.*

One-third of the above was consumed daily for a three-day period. The resulting feces weighed 270 grams moist, and 55.6 grams air-dry, and contained:

	Percent	Grams
Moisture.....	5.36	2.98
Ash.....	19.50	10.85
Protein.....	11.90	6.60
Fat.....	31.20	17.34
Crude fiber.....	1.40	.77
N-free extract.....	30.60	17.03

The protein in the feces of this period represents metabolic products from the digestive juices and intestinal walls as well as some unabsorbed protein from the milk. Deducting this from the protein eliminated in the feces during the soy bean period we have $18.82 - 6.60 = 12.22$ grams, which represents the unabsorbed protein from the wheat flour and soy bean meal. This gives a coefficient of digestibility for the total protein of the bread of 91.3. Assuming that protein of patent wheat flour is 88.6¹¹ per cent digestible the coefficient of digestibility of the soy bean meal protein becomes 93. This is hardly fair, however, since the coefficient 88.6 was obtained without making a cor-

* The agar contained 6.35 percent of ash and 15.75 percent of moisture.

rection for metabolic products in the feces. We feel safe in concluding, however, that soy bean meal prepared as in this experiment is as digestible as regards its protein as is the protein of fine wheat flour which stands supreme among the cereal grains in this respect.

The carbohydrates of bread made from fine wheat flour are 97.7 per cent absorbed in man,¹¹ milk sugar 99¹² per cent and cane sugar probably 100 per cent. Using these values the nitrogen-free extract of the soy bean meal is found to have a coefficient of digestibility of 96.9 per cent.

EXPERIMENT II.

In this experiment the soy bean meal was prepared as a porridge by cooking five hours in a double boiler. This sample of meal contained more grit than that used in Experiment I, but not enough to increase the ash content greatly. It had the following composition:

	Percent
Moisture.....	4.17
Ash.....	5.80
Protein.....	49.31
Crude fiber.....	5.10
Fat.....	6.50
N-free extract.....	29.12

The diet for the three-day period contained the following, approximately one-third being eaten each day:

	Grams	Protein Grams	Fat Grams	N-free Extract Grams	Calories
Milk.....	2000	70	80.	94	1376
Butter.....	150	...	127.5	...	1147
Cane sugar.....	300	...	...	300	1200
Soy bean meal.....	370	182	24.0	108	1375
Total.....	2750	252	231.5	502	5098
Per Day.....	917	84	77.2	167	1699

The fecal residue from this food weighed 224 grams moist and 58.1 grams air dry and contained:

	Percent	Grams
Moisture.....	4.40	2.56
Ash.....	20.64	11.19
Protein.....	39.90	23.20
Crude fiber.....	7.00	4.06
Fat.....	18.96	11.00
N-free extract.....	9.00	5.22

Assuming that 6.06 grams of protein represents the unabsorbed protein of the milk plus the metabolic protein from the digestive fluids, etc., an assumption that can not be far from the truth, then the unabsorbed protein from the soy bean meal must be $23.20 - 6.60 = 16.60$ grams. This gives a coefficient of digestibility for the protein of the soy bean meal of 90.9. If the carbohydrates of milk are 99 and cane sugar 100 per cent absorbed then the coefficient of digestibility for the nitrogen-free extract of the soy bean meal is 96. In this experiment, as in Experiment I, we cannot calculate accurately the digestibility of the fat but we were not particularly concerned with that phase of the subject at this time. By adopting the proper experimental procedure one might determine satisfactorily the digestibility coefficient of soy bean fat, but for that purpose the amount of the experimental fat should be largely increased while other fats in the diet should be reduced to a minimum.

Summary: The protein of soy bean meal, prepared as a bread by mixing with wheat flour or as a porridge, is highly digestible by man. The digestibility factors obtained in the two experiments were 91.3 and 90.9.

The carbohydrates of soy bean meal appear to be much more highly digestible and less prone to intestinal fermentation than are the carbohydrates of the common white bean. The digestibility factors obtained in two experiments were 96.9 and 96.

The chemical composition, digestibility and palatability of foods prepared from soy bean meal from which most of the oil has been expressed, indicate that such a meal is an excellent food for man.

REFERENCES.

1. Oshima, Bul. 159 (1905), U. S. Dept. Agr. Office Exp. Stations.
2. Bul. 28, U. S. Dept. Agr. Office Expt. Stations.
3. Street and Bailey, *J. Ind. Eng. Chem.* 7, 853, (1915).
4. Mendel and Fine, *J. Biol. Chem.*, 10, 447, (1914).
5. Bull. 187, U. S. Dept. Agr. Office Expt. Stations.
6. Daniels and Nichols, *J. Biol. Chem.*, 32, 91, (1917).
7. McCollum, Simmonds and Pitz, *J. Biol. Chem.*, 29, 521, (1917).
8. Osborne and Mendel, *J. Biol. Chem.*, 32, 369, (1917).
9. Gephart and Csonka, *J. Biol. Chem.*, 19, 521, (1914).
10. Bul. 107, U. S. Dept. Agr. Bureau Chem.
11. Report Maine Expt. Station, 1898.
12. Farmers Bul. 363, 22.

Date of Publication, June 30, 1918.