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Badenhop,A.F.; Hackler,L.R.

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A.F. BADENHOP[1] and L. R. HACKLER
New York State Agricultural Experiment Station
Department of Food Science & Technology, Cornell University, Geneva, N.Y. 14456

PROTEIN QUALITY OF DRY ROASTED SOYBEANS: AMINO ACID COMPOSITION AND PROTEIN EFFICIENCY RATIO

SUMMARY—A study was undertaken to determine the effect of the dry-roasting process on the quality of soybean protein as indicated by amino acid analyses and PER. Amino acid analyses revealed losses in tryptophan, available and total lysine, cystine and histidine of 35, 31, 17, 15 and 6% respectively. These losses are reflected in both the essential amino acid index (EAAI) and PER. Average EAAI values decreased with increasing degree of roast (68.4, 67.7 and 63.8) compared with a value of 71.4 for the raw samples. The PER values for the same roasted samples were 1.70, 1.46 and 1.28 respectively. A depressed PER value of 0.6 was obtained for the raw sample because of anti-nutritional factors in the raw beans. Results indicate that the dry roasting process is a means of producing a palatable, nutritious food from soybeans. However, optimum palatability is gained at the expense of protein utilization.

INTRODUCTION

THE ROASTING OF peanuts, tree-nuts, coffee, and other products includes a rapid dehydration followed by a partial pyrolysis. The process is carried out mainly for the desirable flavor changes produced in the product. In some cases the process also imparts other beneficial changes, such as improved texture and color. Also, as in the roasting of soybeans, the process may improve nutritional quality by destroying substances such as trypsin inhibitor.

There are at least two types of roasting processes. The simplest and most direct form is often termed "dry roasting" and involves heating of the product in air and/or a mixture of gases from the heat source. Dry roasting is employed in the coffee and cocoa processing industries, to a considerable extent in the peanut processing industry, and to some extent in the tree-nut processing industry. The other type involves the heating of the product in an oil or fat and is often termed "oil roasting" or "deep-fat frying." Oil roasting is used extensively in the peanut and tree-nut processing industries, as well as in other industries such as the potato chip processing industry.

In the case of peanuts and other tree-nuts, a desirable texture can be achieved merely by roasting the shelled raw product without any pretreatment other than perhaps a preliminary drying or curing operation or, in some cases, a blanching operation to loosen and remove skins or hulls. The roasting of soybeans without some pretreatment results in a product with an extremely hard texture.

The roasting of soybeans is not a new process. Soybeans have been roasted for centuries in Japan for the production of kinako. Kinako was originally made in the home by roasting soybeans in an earthenware pan over an open flame. The resulting roasted beans were then ground into a powder which was used as a coating or ingredient in other foods (Fukushima, D., 1968, personal communication).

In this country, considerable attention was directed toward the soybean as a source of food during the early 1940's, when, because of World War II, various sources of high protein food were quickly becoming limited. In this connection considerable work was done on the production of a roasted soy nut which could be salted and consumed like other nutmeats, or utilized in candy products in place of peanuts. The Borden Soy Processing Company used a procedure which involved soaking the beans followed by a dry roasting process in order to produce a soy nut with a desirable tender texture (Anon., 1948). Another product was made by deep-fat frying soybeans which had been subjected to a previous soaking step (Hale, 1941 and Blumenthal, 1947).

A previous report (Badenhop et al., 1968) described the processing operation of dry roasting as applied to soybeans, and presented the evaluation of the resulting soy nut product in terms of taste panel acceptability and the results of color, texture, and bulk density measurements. That report indicated that the most acceptable sample, in terms of flavor and texture, was obtained by roasting soybeans with an initial moisture of approximately 53% to an end point of 180°C.

The beneficial effects of a mild heat treatment of soybean protein used to destroy growth inhibiting substances such as trypsin inhibitor have been well established and need no elaboration here. Several workers have determined the effects of excessive heat on the nutritional properties of soybean protein. Worthy of note is the work of Rios Iriarte and Barnes (1966), Hacklet et al. (1963) and Riessen et al. (1947). Rios Iriarte and Barnes (1966) found that the overheating of soybean protein caused a destruction of the amino acids lysine, arginine, and cystine as measured chemically by the analysis of acid hydrolysates. They did not analyze for trytophan. The only factors found responsible for the decreased nutritive value of excessively heated soybean protein were a destruction of cystine and a decrease in nitrogen absorbability. Hackler et al. (1965) evaluated the effect of heating soy milk on the nutritional quality of the protein. They found that heating soy milk @ 121°C for 32 min or longer resulted in a lowering of

[1]Present address: Cooperative Extension Service, College of Agriculture, University of Georgia, Athens, Ga. 30601.

Table 1–Description of samples.

Sample number	Time of Soak @ 50°C (min)	Approx. moisture content after soak (as is basis) %	Degree of roast expressed as final temp. °C	Moisture content after roasting (as is basis) %
1	80	43	170	2.85
2	80	43	180	2.16
3	80	43	185	1.83
4	100	48	170	2.81
5	100	48	180	2.27
6	100	48	185	1.81
7	144	53	170	2.83
8	144	53	180	2.41
9	144	53	185	1.94
10	240	59	170	3.82
11	240	59	180	2.81
12	240	59	185	2.41
13	0	12	Not dried	–
14	80	43	Freeze dried	–
15	240	59	Freeze dried	–

the PER value and a decrease in available lysine. Stillings and Hackler (1965) also studied the effects of deep fat frying on the amino acid content of tempeh and found that the content of most amino acids declined after deep fat frying for 7 min. Lysine and cystine were found to be most susceptible to heat destruction. Riessen et al. (1947) observed that excessive heat treatment of soybean protein decreased the liberation of each of the essential amino acids by pancreatic enzymes, but decreased the liberation by acid of cystine, arginine and tryptophan without affecting the release of the other essential amino acids.

In the roasting process the temperatures attained are considerably higher than needed to destroy trypsin inhibitor and may indeed be detrimental to the nutritional quality of the protein. For this reason the present investigation was conducted to determine the effect of the roasting process on the quality of soybean protein as indicated by amino acid analyses of acid hydrolysates and protein efficiency ratio (PER) determinations.

EXPERIMENTAL

Sample preparation

Certified seed soybeans (var. Harosoy-63) were size-graded, using a Clipper Mill (Model M-2B), to a size range of 16–18 mesh. Samples of beans were then soaked in water at 50°C for four different periods of time (80, 100, 144, and 240 min). The soaking operation increased the moisture content of the beans to levels of 43, 48, 53, and 59%, respectively. After soaking, the beans were drained and held in a closed container for 1 hr in order to allow for moisture equilibration within the beans. Small gas-fired coffee sample roasters manufactured by the Jabez Burns Company (now part of Blaw Knox Corporation) were used for the roasting operation. The temperature of the roasters prior to charging was approximately 400°C. The end point of the roast was determined by holding a thermometer in the tumbling beans during the final minutes of roasting. Samples from each of the four moisture levels were roasted to end points of 170, 180, and 185°C. The average temperature of the beans after roasting was also determined by dumping batches directly from the roasters into a Dewar flask and observing the maximum temperature. These were 160, 168, and 175°C respectively. The time of roast for all of the samples (average time = 31 min 55 sec) was approximately equalized by adjusting the size of the charge to the roasters so that the weight of moisture removed per batch was nearly constant for all of the samples. In addition to the 12 roasted samples, 3 samples of unroasted beans were prepared for comparison. One of these was untreated and the other two were prepared by soaking beans for 80 and 240 min, after which they were drained and freeze dried. A simplified description of the 15 samples prepared for this study is given in Table 1.

Chemical analyses

The soybean samples were analyzed for protein (N × 6.25) by the micro-Kjeldahl procedure as outlined in AOAC (1960). Samples were prepared for amino acid analysis by acid-hydrolysis of the protein using 6N HCl at 110°C for 22 hrs. The hydrolysates were fil-

Table 2–Amino acid composition g/16g N and essential amino acid indices of roasted samples and unheated controls.[a]

Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Aspartic acid	10.8	11.3	10.5	11.8	11.1	10.9	11.3	10.9	10.3	10.4	11.0	10.9	11.5	11.0	11.1
Threonine	3.95	4.51	4.21	3.91	4.30	3.97	4.09	4.24	3.74	3.81	4.36	3.90	4.66	3.71	3.88
Serine	4.86	4.84	4.67	5.00	4.99	4.78	4.96	4.76	4.84	4.87	4.90	4.85	4.99	5.31	4.91
Glutamic acid	18.0	18.6	17.3	18.2	18.6	17.9	18.4	18.0	17.9	16.5	18.2	17.7	18.4	17.2	16.7
Proline	4.30	5.36	5.56	5.06	5.27	4.74	5.50	5.02	4.82	5.09	5.11	4.69	5.44	4.76	4.97
Glycine	3.92	4.13	3.77	4.12	4.07	4.06	4.05	4.02	4.02	3.78	4.07	3.91	4.26	3.79	3.92
Alanine	4.11	4.32	4.00	4.28	4.27	4.25	4.28	4.26	4.21	3.91	4.17	4.05	4.23	3.91	3.97
Valine	4.08	4.28	4.01	4.23	4.18	4.11	4.31	4.14	4.11	3.91	4.18	3.98	4.30	3.95	4.12
Cystine	1.45	1.24	1.21	1.43	1.24	1.21	1.28	1.30	1.16	1.31	1.18	1.23	1.52	1.40	1.42
Methionine	1.06	1.08	0.95	1.05	1.01	0.92	1.07	1.06	1.07	0.95	1.12	1.01	1.04	0.94	1.04
Isoleucine	3.74	3.86	3.58	3.93	3.74	3.68	3.84	3.81	4.51	3.52	3.80	3.68	3.94	3.67	3.63
Leucine	7.40	7.40	7.16	7.75	7.54	7.51	7.43	7.56	7.42	7.02	7.37	7.48	7.80	7.65	7.44
Tyrosine	3.25	2.89	2.84	3.06	3.17	2.92	3.08	3.12	3.10	3.12	3.64	3.10	3.02	3.04	3.00
Phenylalanine	4.30	4.39	3.98	4.36	3.82	4.52	4.48	4.37	4.53	4.12	4.79	4.40	4.64	4.38	4.28
Lysine	5.18	4.88	4.21	5.41	4.92	4.52	5.40	4.93	4.61	4.94	5.07	4.64	6.19	5.63	5.79
Histidine	2.38	2.47	2.26	2.41	2.39	2.40	2.42	2.41	2.39	2.34	2.45	2.24	2.50	2.65	2.38
Arginine	7.03	7.07	6.58	7.20	7.01	6.89	7.20	6.75	6.94	6.88	6.80	6.66	7.47	7.20	7.42
Tryptophan	1.20	1.00	0.94	1.14	1.10	0.90	1.15	1.05	0.74	1.13	1.11	1.01	1.51	1.66	1.53
Available Lysine	3.65	2.83	2.14	3.43	3.10	2.08	3.41	2.85	2.70	3.33	2.97	2.85	4.11	4.58	4.14
Essential Amino Acid Index	68.4	66.9	63.1	69.2	66.6	64.1	69.0	67.4	64.4	64.9	68.7	57.8	73.8	69.6	70.1

[a]See Table 1 for description of samples.

Table 3–Average amino acid composition g/16g N of roasted soybean samples and unheated controls.

	170°C Avg.	180°C Avg.	185°C Avg.	Avg. of all roasted samples	Avg. of all unheated samples
Aspartic acid	11.1	11.1	10.7	11.0	11.2
Threonine	3.94	4.35	3.96	4.08	4.08
Serine	4.92	4.85	4.79	4.86	5.07
Glutamic acid	18.1	18.3	17.7	18.1	17.4
Proline	5.15	5.19	4.95	5.10	5.06
Glycine	3.97	4.07	3.94	3.99	3.99
Alanine	4.15	4.26	4.13	4.18	4.04
Valine	4.13	4.20	4.05	4.13	4.12
Cystine	1.37	1.24	1.20	1.27	1.50
Methionine	1.03	1.07	0.99	1.03	1.01
Isoleucine	3.76	3.80	3.86	3.81	3.75
Leucine	7.40	7.47	7.39	7.42	7.63
Tyrosine	3.13	3.21	2.99	3.11	3.02
Phenylalanine	4.32	4.49	4.36	4.39	4.43
Lysine	5.23	4.95	4.50	4.89	5.87
Histidine	2.39	2.43	2.32	2.38	2.54
Arginine	7.23	7.39	7.06	7.23	7.45
Tryptophan	1.16	1.07	0.90	1.04	1.57
Available Lysine	3.45	2.94	2.44	2.94	4.28
Essential Amino Acid Index	68.4	67.7	63.8	66.5	71.4

Table 4–Effect of roasting process on the nutritive value of soybean protein as indicated by PER values.

Sample No. used as diet supplement	Average daily weight gain (g)[a]	Average daily feed consumption (g)[a]	PER[a,b]	Diet Protein %
1	1.63 ± .15	9.33 ± .67	1.51 ± .05	9.19
2	1.52 ± .14	8.77 ± .31	1.51 ± .10	9.13
3	1.12 ± .08	8.51 ± .74	1.17 ± .10	9.50
4	1.95 ± .13	9.61 ± .38	1.87 ± .07	8.63
5	1.58 ± .10	9.08 ± .48	1.50 ± .04	9.25
6	.81 ± .07	7.15 ± .29	0.99 ± .07	9.13
7	1.77 ± .12	9.34 ± .39	1.59 ± .06	9.44
8	1.33 ± .10	8.49 ± .27	1.30 ± .06	9.50
9	1.06 ± .06	7.97 ± .22	1.24 ± .06	8.63
10	2.18 ± .15	10.68 ± .24	1.83 ± .10	8.88
11	1.58 ± .11	8.69 ± .34	1.51 ± .06	9.56
12	1.29 ± .20	8.18 ± .52	1.73 ± .18	7.00
13	0.58 ± .11	6.01 ± .40	0.80 ± .14	8.81
14	0.32 ± .14	5.42 ± .45	0.48 ± .18	8.06
15	0.45 ± .19	6.24 ± .24	0.57 ± .09	10.06

[a]Each datum represents the mean for each group of rats ± the standard error of the mean.

[b]Adjusted to a casein standard with a PER of 2.5.

tered, dried, and taken up in pH 2.2 sodium citrate buffer. Amino acid composition of the samples was determined by ion-exchange column chromatography using a Technicon amino acid auto analyzer (Model NC-3). Cystine was analyzed by conversion to cysteic acid using the method of Moore (1963) followed by chromatography. Available lysine was determined using the method of Rexen and Christensen (1967). Tryptophan was determined using the method of Horn and Jones (1945).

Animal feeding study

Protein efficiency ratios (PER) were determined by growth studies using male weanling albino rats. The soybean supplements were used as the sole protein source in the test diets. These diets were fed ad libitum to groups of 10 rats for 28 days. A casein control was also included and the resulting PER values were adjusted to the casein diet standardized to a PER of 2.5. Complete details of the experimental methods used in the rat growth studies have been reported previously, Hackler et al. (1963).

RESULTS & DISCUSSION

TOTAL AMINO ACID analyses (Table 2) indicate that the effect of roasting on the amino acid composition of soybean protein is confined mainly to the destruction of total and available lysine, cystine and tryptophan. Even these amino acids were not consistently affected by the degree of roast. Total lysine content was found to be inversely related to degree of roast in all but the three samples roasted from 59% moisture. Available lysine, however, was inversely related to the degree of roast in the samples from all 4 moisture levels. Cystine content was inversely related to degree of roast in the samples roasted from 43 and 48% but not those from 53 and 59% moisture. Tryptophan content was inversely related to degree of roast in the samples from all 4 moisture levels.

In order to show the combined effects of the roasting process on the essential amino acids, the essential amino acid index (EAAI) was also calculated according to the method of Mitchell (1954). These values for the 15 samples (Table 2) indicate that the EAAI is inversely related to the degree of roast in all but the three samples with the highest initial moisture content.

When the four samples which were roasted to each of the three degrees of roast are averaged, one obtains the values contained in Table 3. Tryptophan, cystine, total lysine and available lysine are all inversely related to the degree of roast. Serine also shows this trend. Also contained in Table 3 are the average of all 12 roasted samples and the average of the three unheated samples. If the difference between these two values is considered to be the average effect of the roasting process on the amino acid composition, tryptophan appears to be the most heat-labile amino acid. Tryptophan content was found to be decreased by 35% during roasting. Following in order of heat lability are available lysine, total lysine, cystine and histidine, decreased by 31, 17, 15, and 6% respectively. Since the most heat-labile amino acids are all essential, or semi-essential, the effect of roasting is reflected in the EAAI values calculated using the averages in Table 3. The EAAI drops from 68.4 for the 170°C samples to 67.7 for the 180°C samples and 63.8 for the 185°C samples. Finally a comparison of the average EAAI of all 12 roasted samples with that of the 3 unheated samples shows a decrease from 71.4 to 66.5 due to the roasting process.

The results of the animal feeding studies (Table 4) indicate that PER is inversely related to the degree of roast. This relationship was noted for samples 4, 5, and 6 and 7, 8, and 9, roasted from moisture contents of 48 and 53% respectively. Samples 1, 2, and 3, roasted from 43% moisture, showed no change in PER between the 170°C and 180°C roasts. For both samples the PER was 1.51. The PER dropped to 1.17 for sample 3, roasted to 185°C. The only other deviation from inverse relationship was noted in sample 12 (185°C roast from 59% moisture). This sample produced a PER of 1.73, a higher value than that obtained from the 180°C roast of the same initial moisture. The explanation for this high value may be the abnormally low protein content of the diet used for measuring the PER value. The average PER values for all samples roasted to each of the three degrees of roast were 1.70, 1.46, and 1.28 for the 170, 180, and 185°C end points respectively.

The values for the average daily weight gain and average daily feed consumption

show that they are both inversely related to the degree of roast from all four initial moisture levels.

The PER values for the 12 roasted samples averaged 1.48 as opposed to an average PER of 0.61 for the unroasted samples. While the roasting process improves the nutritive value of soybeans by destroying the activity of trypsin inhibitor, the resulting PER values are not as high as those obtained by more gentle heating. PER values greater than 2.00 are easily obtained for soybean protein that has been properly heat treated (autoclaving at 121°C for 5–10 min) in the presence of sufficient moisture (Hackler et al., 1965). Such a treatment will achieve the desired destruction of trypsin inhibitor activity without significant destruction of the essential amino acids. The higher temperatures attained during the roasting process result in the destruction of some of the essential amino acids. The loss of essential amino acids contributes to the lowering of the PER value.

Based on these results and the data reported previously on the quality and acceptability of roasted soybeans (Badenhop et al., 1968), it is apparent that the dry roasting process is a simple method of producing an edible food from soybeans. Roasted soybeans have an appearance and flavor resembling roasted Spanish peanuts. The texture is quite different, because of the grossly different proportions of fat and protein in the two seeds. One would expect the presence of the hull to have an undesirable effect on the mouth feel of the roasted beans; their presence is of little consequence, however, since they break up easily during mastication. More of a mouth feel problem is caused by the inherent dryness of the product presumably a result of the relatively low fat content. Even this problem is minor in terms of over-all acceptability. Both mouth feel and flavor can be improved considerably by coating the roasted beans with vegetable oil or margarine and salt to produce a salted nut-like product similar to Spanish peanuts.

Roasted soybeans can serve as a high protein snack food or be used as a valuable protein-enriching adjunct in the candy industry. Another possibility is the grinding of roasted soybeans with the addition of sufficient oil to produce a peanut butter analog.

When the similarity of roasted soybeans to roasted peanuts is contrasted with the raw product cost ratio (ca. 1 to 5), extensive product development using roasted soybeans as an ingredient would seem to merit considerable attention.

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