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The Content of Nine Mineral Elements in Raw and Cooked Mature Dry Legumes

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Three lots each of ten kinds of mature dry legumes were purchased in the Virginia market. Determinations were made of the amounts of nine mineral elements—calcium, copper, iron, magnesium, manganese, phosphorus, potassium, sodium, and zinc—in raw and cooked legumes and cooking water from each lot. Analyses of variance showed significant differences in mineral element content among four classes of field beans bearing the scientific name *Phaseolus vulgaris* L., and between baby and large lima beans (*Phaseolus limensis* L). Minerals in cooked legumes were about one-third to one-half of the values in raw legumes. Variability in mineral contents due primarily to differences among lots was least for zinc and greatest for phosphorus. Data on minerals in raw legumes were in reasonably good agreement with other American data, but frequently differed markedly with data from other countries. Cooking water contained measurable amounts of all the minerals, and relatively high amounts of magnesium, phosphorus, and potassium.

Mature dry legumes are important in the diets of many population groups around the world. Food balance figures (Aykroyd and Doughty, 1969) showed per capita consumption to range from 3 to 7 g daily in countries such as Sweden, Argentina, and Australia, to 71 g daily in India. For the United States, per capita daily consumption was 16 g.

Legumes are recognized as an important source of protein (Aykroyd and Doughty, 1969). However, their potential contribution to dietary mineral needs is less well known. Dry beans and peas are known to be good sources of iron (Peterkin et al., 1975), potassium (Murphy and Mangubat, 1973), zinc (Murphy et al., 1975), and magnesium and phosphorus (Consumer and Food Economics Research Division, 1971).

Information is needed on the content and variability of mineral elements in mature dry legumes as currently marketed in the United States. In particular, data are needed for minerals in both raw and cooked legumes from the same purchase lot, to determine effects of cooking. Such data should provide guidelines for use in the nutrient labeling of mature dry legumes.

This paper reports the content of nine mineral elements—calcium, copper, iron, magnesium, manganese, phosphorus, potassium, sodium, and zinc—in 10 different kinds of legumes, raw and cooked, and in the cooking water from each lot of cooked legumes. A previous paper (Meiners et al., 1976) reported data on the proximate composition and yield of the same lots of legumes.

MATERIALS AND METHODS

Three lots of ten different kinds of mature dry legumes were purchased in the Virginia market. From each lot, duplicate samples were selected for analysis in the raw state; two additional replicates were selected for analysis after cooking. Procedures for cooking and preparation of raw and cooked samples and of cooking water were previously described (Meiners et al., 1976).

Samples were ashed by using a nitric acid–perchloric acid method and were analyzed for calcium, copper, iron, magnesium, manganese, potassium, sodium, and zinc, by procedures established for the Perkin-Elmer atomic absorption spectrophotometer (1968). In preliminary trials, the reliability of the methods was established. Phosphorus was determined from an aliquot of the ash solution by the colorimetric method of Fiske and Subbarow (1925). Analyses of variance and least significant differences among means were determined by the computer program designed and implemented by Barr and Goodnight (Service, 1972). For some comparisons, significance of differences among means was determined with multiple range and multiple-F tests (Duncan, 1955).

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Table I. Mineral Element Content of Ten Kinds of Raw, Mature, Dry Legumes[a]

Kind of legume	mg/100 g edible portion								
	Calcium	Copper	Iron	Magnesium	Manganese	Phosphorus	Potassium	Sodium	Zinc
Phaseolus vulgaris									
Navy beans	135.5 ± 2.0	0.80 ± 0.02	5.34 ± 0.02	162.8 ± 2.3	1.02 ± 0.01	453 ± 6	820.8 ± 15.0	1.66 ± 0.03	2.17 ± 0.04
Great northern beans	181.2 ± 2.9	0.82 ± 0.02	6.87 ± 0.08	178.3 ± 4.7	1.52 ± 0.02	458 ± 3	1087.3 ± 21.1	3.60 ± 0.04	2.12 ± 0.04
Pinto beans	111.7 ± 3.6	0.67 ± 0.06	7.04 ± 0.15	170.8 ± 7.9	1.52 ± 0.13	510 ± 69	1156.2 ± 43.4	2.51 ± 0.10	2.21 ± 0.05
Red kidney beans	59.5 ± 2.6	0.69 ± 0.01	7.47 ± 0.23	123.0 ± 5.1	1.43 ± 0.10	374 ± 13	1300.7 ± 11.7	2.45 ± 0.03	2.52 ± 0.04
Signif. of diff.[b]	**	**	**	**	**	NS	**	**	**
LSD[c]	10.3	0.12	0.52	19.7	0.31		94.6	0.22	0.15
Phaseolus limensis									
Baby lima beans	76.1 ± 1.7	0.64 ± 0.01	6.79 ± 0.06	163.6 ± 1.5	1.64 ± 0.02	397 ± 3	1157.7 ± 26.1	3.76 ± 0.14	2.42 ± 0.01
Large lima beans	57.2 ± 1.2	0.84 ± 0.00	8.28 ± 0.16	182.5 ± 3.2	1.85 ± 0.02	440 ± 11	1630.6 ± 35.1	1.90 ± 0.11	2.83 ± 0.03
Signif. of diff.[b]	**	**	**	**	**	**	**	**	**
Vigna unguiculata (L.) Walp									
Cowpeas (blackeyes)	69.0 ± 0.9	0.91 ± 0.01	7.97 ± 0.28	206.3 ± 7.1	1.25 ± 0.04	518 ± 6	838.3 ± 18.5	8.39 ± 0.69	2.89 ± 0.07
Cicer arietinum L.									
Chickpeas	103.1 ± 3.1	0.86 ± 0.02	5.82 ± 0.10	91.7 ± 0.5	1.71 ± 0.10	354 ± 24	692.3 ± 31.3	12.69 ± 1.04	2.86 ± 0.09
Pisum sativum L.									
Green split peas[d]	34.9 ± 0.8	0.63 ± 0.01	2.22 ± 0.06	87.2 ± 3.3	1.08 ± 0.03	348 ± 46	1075.4 ± 13.6	2.95 ± 0.08	2.04 ± 0.04
Lens culinaris Medic									
Lentils (split)[d]	47.2 ± 1.0	0.89 ± 0.01	9.56 ± 0.47	90.7 ± 0.6	1.42 ± 0.03	522 ± 34	861.9 ± 30.7	2.49 ± 0.06	3.15 ± 0.04

[a] Each value is the mean ± standard error of the mean for four analyses from each of three purchase lots (N = 12). [b] Significance of difference: **, $P = 0.01$; NS = not significant. [c] Least significant difference (LSD) is for the specified level of significance. [d] Without seed coat.

Table II. Mineral Element Content of Ten Kinds of Cooked Mature Dry Legumes[a]

Kind of legume	mg/100 g								
	Calcium	Copper	Iron	Magnesium	Manganese	Phosphorus	Potassium	Sodium	Zinc
Phaseolus vulgaris									
Navy beans	68.7 ± 1.2	0.33 ± 0.00	2.59 ± 0.08	57.0 ± 2.2	0.43 ± 0.01	156 ± 5	297.6 ± 5.2	1.57 ± 0.02	1.08 ± 0.04
Great northern beans	70.7 ± 2.1	0.31 ± 0.01	2.67 ± 0.02	47.1 ± 1.6	0.58 ± 0.01	178 ± 3	390.2 ± 17.6	2.63 ± 0.10	0.90 ± 0.02
Pinto beans	48.0 ± 1.9	0.25 ± 0.03	3.28 ± 0.09	54.6 ± 0.9	0.65 ± 0.08	163 ± 21	472.7 ± 43.0	2.12 ± 0.08	1.30 ± 0.04
Red kidney beans	19.5 ± 1.4	0.24 ± 0.00	3.74 ± 0.31	44.3 ± 1.4	0.52 ± 0.04	123 ± 6	398.8 ± 7.2	2.34 ± 0.03	1.10 ± 0.01
Signif. of diff.[b]	**	**	**	**	*	**	**	**	**
LSD[c]	6.0	0.06	0.62	5.7	0.13	41.4	86	0.26	0.12
Phaseolus limensis									
Baby lima beans	27.4 ± 0.8	0.23 ± 0.01	2.68 ± 0.04	41.7 ± 1.2	0.59 ± 0.01	125 ± 2	327.7 ± 9.7	2.77 ± 0.15	0.98 ± 0.01
Large lima beans	19.1 ± 0.5	0.28 ± 0.00	3.34 ± 0.11	41.5 ± 0.7	0.55 ± 0.01	124 ± 6	506.2 ± 29.2	2.01 ± 0.06	0.99 ± 0.01
Signif. of diff.[b]	**	**	**	NS	**	NS	**	**	NS
Vigna unguiculata (L.) Walp									
Cowpeas (blackeyes)	26.9 ± 1.0	0.32 ± 0.01	3.10 ± 0.05	46.9 ± 0.8	0.43 ± 0.02	170 ± 5	267.2 ± 5.5	4.87 ± 0.53	1.23 ± 0.05
Cicer arietinum L.									
Chickpeas	55.6 ± 0.5	0.47 ± 0.02	3.38 ± 0.06	47.1 ± 1.2	0.98 ± 0.07	190 ± 7	325.8 ± 3.0	7.95 ± 0.91	1.74 ± 0.05
Pisum sativum L.									
Green split peas[d]	13.5 ± 0.4	0.19 ± 0.01	1.11 ± 0.09	31.7 ± 0.7	0.40 ± 0.01	80 ± 4	406.1 ± 42.8	2.22 ± 0.06	0.87 ± 0.01
Lens culinaris Medic									
Lentils (split)[d]	18.2 ± 0.3	0.25 ± 0.01	3.98 ± 0.26	30.2 ± 1.2	0.50 ± 0.01	186 ± 20	391.5 ± 42.0	2.11 ± 0.08	1.18 ± 0.02

[a] Each value is the mean ± standard error of the mean for four analyses from each of three purchase lots (N = 12). [b] Significance of difference: **, $P = 0.01$; *, $P = 0.05$; NS = not significant. [c] Least significant difference (LSD) is for the specified level of significance. [d] Without seed coat.

RESULTS AND DISCUSSION

The mineral element content of raw legumes is given in Table I. The legumes were relatively high in calcium, iron, magnesium, phosphorus, and potassium, and low in sodium. However, considerable variation was found among the kinds of legumes in the content of several of the minerals. For example, calcium in these dry legumes ranged from 35 mg per 100 g of raw split peas (a product with seed coat removed) to 181 mg per 100 g of uncooked Great Northern beans. Magnesium values showed an increase of more than twofold from low to high, ranging from about 90 mg per 100 g of chickpeas, green split peas, and lentils (split, without seed coat) to more than 200 mg per 100 g of dry cowpeas. The trace elements copper, manganese, and zinc varied in content among the different legumes within much narrower limits.

In a few instances, the content of a particular mineral element in a specific kind of legume was markedly different from the contents of that element in other legumes. The iron content of green split peas, for example, was considerably lower than iron in other legumes. Sodium was much higher in chickpeas and cowpeas than in other legumes.

Analyses of variance showed significant differences (1% level) among four kinds of beans bearing the scientific name *Phaseolus vulgaris* L. for all minerals except phosphorus. Least significant differences given in Table I can be used to determine how many of the values compared were significantly different from a specified value. No pattern of differences was seen in mineral contents of any one kind of bean as compared with other kinds of *P. vulgaris*, that is, no one bean was consistently higher or lower in mineral element content than the other three beans.

Analyses of variances on two kinds of *Phaseolus limensis* L. showed that baby lima beans differed significantly (1% level) from large lima beans in content of all nine minerals. Baby limas were higher in calcium and sodium, but were lower than large limas in content of the seven other minerals.

Table II gives data on mineral elements in cooked drained legumes. In general, data for minerals in cooked legumes were about one-third to one-half of the values for the paired samples of raw legumes as given in Table I. This relationship was expected, as cooked weight/dry weight ratios for the beans ranged from 2.07 to 2.94 (Meiners et al., 1976). The increased weight in the cooked beans was from absorbed water, which would have a diluting effect on the mineral concentration of the beans.

Analyses of variance calculated on the minerals in the four kinds of cooked *P. vulgaris* beans (Table II) showed similar, but not identical, results to those found for raw *P. vulgaris* beans (Table I). The major change from data on raw legumes was the difference found for phosphorus in cooked beans. Least significant differences (LSD's) showed this difference to be significant only when the phosphorus content of cooked red kidney beans, 123 mg per 100 g, was compared with that of cooked Great Northern beans, 178 mg per 100 g.

Cooked baby lima beans were higher in calcium, manganese, and sodium, and lower in copper, iron, and potassium than were cooked large lima beans. Magnesium, manganese, phosphorus, and zinc thus showed different patterns of relationships between baby and large limas for raw and cooked beans.

Variability for an individual mineral element within a specific kind of legume is shown by the standard errors of the mean reported in Table I for raw legumes and in Table II for cooked legumes. For both cooked and raw legumes, variability was primarily due to differences among purchase lots, as replicate values for the same lot of legumes were nearly always in close agreement.

Coefficients of variation (standard deviation expressed as percent of the mean) showed that variability was slightly greater in cooked legumes, which had an average coefficient of variation of 13%, than in raw legumes, for which the coefficient of variation averaged 10%. Overall, variation was least for zinc and greatest for phosphorus. In terms of kind of legume, variation was least for navy beans and baby lima beans, and greatest for pinto beans.

Several reports published within the past few years provided data on content of one or more mineral elements in one or more kinds of the mature dry legumes included in this research (Walker and Hymowitz, 1972; Rockland et al., 1973; de Moraes and Angelucci, 1971; Roychowdhury et al., 1962; Kadwe et al., 1974; Sinha and Tripathi, 1973; and Kuzayli et al., 1966). Of these references, only Walker and Hymowitz and Rockland et al. reported data on dry legumes grown in North America. Data from these sources, and from Agriculture Handbook 8 (Watt and Merrill, 1963) were compared with data from the present study.

Comparisons of data for the nine minerals showed that generally the present data were in reasonably good agreement with other North American data, but frequently differed markedly with data from other countries (Brazil, Lebanon, and India). Data for calcium in *P. vulgaris* beans from the present study were generally in good agreement with data on other *P. vulgaris* samples from the literature, but calcium values for other kinds of legumes tended to be lower in the current study than in the sources cited above. Copper values reported in Table I were in good agreement with data from Walker and Hymowitz on U.S.-grown samples, but were considerably lower than data from India by Roychowdhury, who found 4.91 mg of copper per 100 g of raw chickpeas and 1.23 mg of copper per 100 g of raw lentils.

Values for iron shown in Table I ranged from 2.22 to 9.56 mg of iron per 100 g of raw legume, and were generally in good agreement with values from other sources, which ranged from 2.76 mg per 100 g of *P. vulgaris* bean (de Moraes and Angelucci, 1971) to 21 mg per 100 g of cowpeas (Kadwe et al., 1974). Data from Handbook 8, ranging from 5.1 to 7.9 mg of iron per 100 g of raw legume, also tended to agree well with iron data in Table I. However, values in Table I for iron in split peas were generally lower, and in lentils were higher, than were comparable values from the literature.

Data for magnesium from the current research were in good agreement with other U.S. data, but tended to be lower than magnesium values from other countries. Values for manganese were generally in good agreement with data from Walker and Hymowitz, whose values ranged from 1.17 mg per 100 g of *P. vulgaris* to 1.79 mg per 100 g of cowpeas. These values were slightly lower than data from Roychowdhury, whose values ranged from 2.2 mg per 100 g of lentils to 4.9 mg per 100 g of dry peas with seed coat, but were lower than Sinha's values for dry peas by a factor of 30.

Values for phosphorus in Table I were in reasonably good agreement with data from other sources except for lentils. Phosphorus in lentils in the study reported here was about double the value found in lentils in other reports.

Potassium content of green split peas was higher in this study than in Agriculture Handbook 8 or Roychowdhury et al. (1962), while values for cowpeas and chickpeas were lower than Handbook 8 values. Cowpeas were lower in the

Table III. Mineral Element Content of Water Drained from Ten Kinds of Cooked Legumes[a]

Kind of legume	mg/100 g								
	Calcium	Copper	Iron	Magnesium	Manganese	Phosphorus	Potassium	Sodium	Zinc
Phaseolus vulgaris									
Navy beans	16.7 ± 1.5	0.24 ± 0.01	1.24 ± 0.03	47.8 ± 2.1	0.07 ± 0.00	92 ± 3	336.6 ± 12.5	1.57 ± 0.03	0.37 ± 0.03
Great northern beans	14.5 ± 0.7	0.22 ± 0.01	1.32 ± 0.02	45.8 ± 1.4	0.10 ± 0.00	124 ± 4	404.5 ± 26.9	2.56 ± 0.14	0.30 ± 0.01
Pinto beans	22.3 ± 1.0	0.19 ± 0.02	3.35 ± 0.18	61.2 ± 2.2	0.36 ± 0.02	138 ± 15	495.8 ± 34.0	1.43 ± 0.15	0.71 ± 0.01
Red kidney beans	13.2 ± 0.9	0.10 ± 0.01	1.96 ± 0.16	37.3 ± 0.9	0.08 ± 0.00	88 ± 5	407.8 ± 6.7	2.02 ± 0.09	0.49 ± 0.03
Signif. of diff.[b]	**	**	**	**	**	**	**	**	**
LSD[c]	3.8	0.05	0.44	6.3	0.04	31	83.2	0.40	0.09
Phaseolus limensis									
Baby lima beans	15.8 ± 0.4	0.15 ± 0.00	1.86 ± 0.05	43.1 ± 1.4	0.22 ± 0.01	75 ± 1	306.3 ± 10.6	3.19 ± 0.09	0.44 ± 0.02
Large lima beans	15.2 ± 0.3	0.16 ± 0.00	3.13 ± 0.09	46.3 ± 0.8	0.38 ± 0.01	99 ± 4	521.6 ± 25.7	1.65 ± 0.03	0.66 ± 0.02
Signif. of diff.[b]	NS	**	**	*	**	**	**	**	**
Vigna unguiculata (L.) Walp									
Cowpeas (blackeyes)	11.4 ± 0.8	0.20 ± 0.01	1.31 ± 0.03	36.2 ± 0.6	0.10 ± 0.01	98 ± 2	253.1 ± 4.8	3.35 ± 0.21	0.33 ± 0.02
Cicer arietinum L.									
Chickpeas	20.3 ± 0.3	0.22 ± 0.01	2.48 ± 0.13	42.8 ± 0.6	0.20 ± 0.02	75 ± 3	372.8 ± 6.1	7.35 ± 0.56	0.57 ± 0.02
Pisum sativum L.									
Green split peas[d]	6.4 ± 0.5	0.15 ± 0.01	0.55 ± 0.03	25.4 ± 1.2	0.16 ± 0.00	52 ± 2	405.8 ± 38.3	2.42 ± 0.17	0.58 ± 0.04
Lens culinaris Medic									
Lentils (split)[d]	7.8 ± 0.3	0.20 ± 0.01	3.04 ± 0.27	22.9 ± 1.2	0.14 ± 0.01	142 ± 18	313.0 ± 23.9	2.29 ± 0.18	0.43 ± 0.01

[a] Each value is the mean ± standard error of the mean for four analyses from each of three purchase lots (N = 12). [b] Significance of differences: **, $P = 0.01$; *, $P = 0.05$; NS = not significant. [c] Least significant difference (LSD) is for the specified level of significance. [d] Without seed coat.

present study (838 mg per 100 g of raw legume) than in Walker and Hymowitz (1972) (1420 mg per 100 g of raw legume). Data on sodium in this study were lower than data from Roychowdhury, who found 125 mg of sodium per 100 g of chickpeas and 28 mg of sodium per 100 g of lentils. In the present study, sodium values in all legumes except cowpeas and chickpeas were low enough for sodium to be considered a trace element, in the same range as zinc and manganese. Zinc values in Table I were in good agreement with data from Walker and Hymowitz, who found 2.23 mg of zinc per 100 g of raw *P. vulgaris* beans and 2.83 mg of zinc per 100 g of raw cowpeas. None of the other sources reported data on zinc.

Data on mineral content of cooking water are given in Table III. The cooking water was found to contain measurable amounts of all of the minerals, and relatively high amounts of magnesium, phosphorus, and potassium. Losses of the different minerals in the cooking water were relatively small for most minerals in most legumes.

For green split peas, which are frequently served as soup, the contents of mineral elements in cooked peas plus cooking water were calculated. These values, expressed per 100 g of cooked peas plus water, were: calcium, 10 mg; copper, 0.17 mg; iron, 0.87 mg; magnesium, 29 mg; manganese, 0.30 mg; phosphorus, 68 mg; potassium, 410 mg; and zinc, 0.74 mg. These values, except for potassium, are approximately 85% of the values for cooked peas alone.

Because the sodium contents of both cooked legumes and the drained water from the legumes were high in relation to sodium values for raw legumes, further investigation into the preparation procedures was made. As part of the preliminary work in setting up this research, a study had been made of the effect of heating the ion-free water in the glass containers used for cooking the legumes. No measurable amounts of sodium were found in the ion-free water, before or after it was heated. The water had a pH of 7.1.

However, further investigation, using cowpeas (blackeyes), showed that the addition of the cowpeas to the ion-free water resulted in a change of pH as follows.

Conditions of measurement	pH (2 measurements)
Ion-free water	7.1
Water and peas	
2 min after mixing	6.0–6.2
Soaked 1 h	5.5–5.5
After heating	5.7–5.7

The sodium content of the ion-free water, pH 7.1, heated for the same time as the cowpea–water mixture, was again found to be essentially zero. However, when the pH of the water was adjusted to 5.5–5.7, the water after heating was found, in two tests, to have a sodium content of 3.73 and 3.21 mg per 100 g. It thus appears that changes in the pH of the cowpea–water mixture resulted in sodium being released from the glass cooking vessel into the cooked cowpeas and/or cooking water. The amounts of sodium released in this way would not be considered nutritionally important for any except perhaps the most severely restricted controlled-sodium diets. However, these data indicate that studies on the effect of preparation on sodium content of foods should be made with caution when glass containers are used for cooking or heating. Values for sodium in legumes cooked in metal containers could be expected to be a little lower than the data given in Table II.

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Effect of Heat, Amylase, and Disulfide Bond Cleavage on the in Vitro Digestibility of Soybean Proteins

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Various protein fractions were prepared from defatted soybean flour based on solubility differences and size on Sephadex G-200. The in vitro digestibility of these fractions by trypsin and by successive pepsin–trypsin treatment was affected by the presence of trypsin inhibitors, native structure of the proteins, and the presence of starch (shown to be present in soybeans). The trypsin inhibitors were destroyed by heating at 100 °C for 30 min at pH 1 but not at neutrality. The native structure of the proteins could be destroyed by heating, particularly at low pH, digestion with pepsin at pH 1, or by cleavage of the disulfide bonds. Cleavage of disulfide bonds increased the in vitro digestibility of the proteins. Prior amylase treatment increased the trypsin digestibility of most of the protein fractions.

With the exception of limiting amounts of methionine and cystine, soybean is an excellent food protein source (Kellor, 1974). However, there are a number of antinutritive compounds in soybeans which may adversely affect the nutritive value. These antinutritive compounds include proteolytic enzyme inhibitors, amylase inhibitors, phytohemagglutinins, phytic acid, flatulents, goitrogenic compounds, saponins, and phenolic compounds (Rackis, 1974). The first three of these can be destroyed by adequate heat treatment and the other compounds are thought not to be of serious nutritional concern, especially in a mixed diet. However, it is of major concern that the biological value and digestibility of soybean proteins are significantly lower than those for egg proteins. Liener (1972) reported the biological value, measured with human subjects, of heat treated full fat soybean flour to be 64 while that of egg was 87. Supplementation of the soybean flour with methionine increased the biological value only to 75. Digestibility values, also measured on human subjects, were 84 and 97 for soybean flour and eggs, respectively, and the digestibility of soybean flour was not improved by addition of methionine.

The presence of active inhibitors and phytohemagglutinins in improperly heat-treated soybean flour undoubtedly accounts for some of the observed decreased digestibility. Rackis (1974) indicated that phytohemagglutinin could account for 25% inhibition of growth of rats on feeding raw soybean flour. Kakade et al. (1969) showed that both selective removal of the trypsin inhibitors and denaturation of protein by heat increased digestibility of the protein. Excessive heat treatment can also lower the digestibility (Kellor, 1974). However, these are not the total explanation for the lowered digestibility. Jaffé (1972) reported that a variety of red beans which did not contain trypsin or chymotrypsin inhibitors still had only 71% digestibility.

The tertiary structure of the proteins affects digestibility and the structure may not be fully destroyed by heat treatment. Fukushima (1968) suggested that the globular molecules of soybean proteins are compactly folded and have a hydrophobic region in the interior which resists proteolysis. The proteins cannot be fully digested until the interior tertiary structure is destroyed. Seidl et al. (1969) reported that, in in vitro studies, isolated black bean

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