Proximate Composition and Yield of 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. Subsamples of each lot were analyzed for proximate components before and after cooking by standard household procedures. Data on yields of cooked legumes were obtained for both weight and volume measures. Lentils had the highest ratio of cooked weight to dry weight, 2.94, and chickpeas had the lowest ratio, 2.07. Protein, fat, and ash values were generally in good agreement with data tabulated in Agriculture Handbook 8, but moisture data were higher, and crude fiber values were much higher than data in Handbook 8. Analyses of variance showed significant differences among four kinds of *Phaseolus vulgaris* beans for all proximate components except crude fiber in cooked beans. Significant differences between baby and large lima beans were found for most proximate components, although for cooked lima beans these differences were nutritionally unimportant.

The advent of nutrient labeling and increased interest of consumers in nutrition have resulted in a greatly heightened interest in the composition of foods. Because labeling of nutrients must be done on the basis of amounts per serving, data are in great demand on weight–volume relationships and on weight and nutrient changes with cooking.

According to the 1965 Household Food Consumption Survey (Consumer and Food Economics Research Division, 1966), mature dry legumes were consumed in relatively large amounts by low-income families in rural areas. From 37 to 50% of rural families with incomes of less than $5000 used dried vegetables during the week surveyed, and the amount used was from 0.58 to 1.08 lb per household per week. Legumes are valued for the content of protein, B vitamins such as thiamin, and minerals such as potassium (Watt and Merrill, 1963). They are also low in lipids.

Recent investigations on North American legumes have centered around the effects of prolonged storage, moisture content, and storage temperature. That high moisture content, extended storage, and high storage temperature contribute to impaired legume cookability has been demonstrated by Muneta (1964), Burr et al. (1968), and Kon (1968). Lipid content was not a determinant in the cooking time of dry beans (Takayama et al., 1965). The chemical composition of selected legumes has been studied in Lebanon (Kuzayli et al., 1966), India (Kadwe et al., 1974; Sinha and Tripathi, 1973), Guatemala (Bressani et al., 1961), and Brazil (deMoraes and Angelucci, 1971). Rockland and Metzler (1967) examined the cooking characteristics of beans, including proximate analyses, in the development of a process for quick cooking of lima and other dry beans. Oke (1967) analyzed Nigerian pulses for proximate components. Eden (1968) studied the proximate composition of spring and winter sown field beans.

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Few recent data have been reported on nutrient contents of samples of commonly consumed legumes as marketed in the United States. In addition, data are lacking on nutrients in cooked legumes, and information is needed on nutrients lost during cooking.

This paper reports research undertaken to determine weight–volume relationships for 10 different kinds of raw and cooked legumes, weight changes with cooking, and proximate composition of raw and cooked legumes and cooking water. The content of nine mineral elements and three B vitamins in the same samples will be reported in companion papers (Meiners et al., 1976).

MATERIALS AND METHODS

Three lots or brands of ten different kinds of legumes were purchased through local Virginia food markets. From each lot, two replicate samples were measured in 1-cup amounts in a standard measuring cup, weighed to the nearest gram, and ground until homogeneous samples were obtained; subsamples were taken for subsequent analyses of each of the raw legumes. For cooking, two 1-cup samples were taken in a similar way from each lot of unground legume. A measured amount of deionized water was weighed (Table I) and added to each sample in a glass container; the mixture was boiled for 2 min, allowed to stand at room temperature for 1 h, and was then simmered according to published guidelines (U.S. Department of Agriculture, 1968) (Table I). Initially, the amount of water used was taken from the USDA guidelines (1968). However, in preliminary trials, it was determined that the recommended amount was not sufficient for all legumes, and an additional amount of ion-free water was added to prevent dryness during cooking. On occasion, a weighed amount of additional water was added to prevent legumes from cooking to dryness thus resulting in different amounts of cooking water. After cooking, the legumes were drained and allowed to cool to room temperature. Weights (grams) and volumes (cups) of cooked product were recorded. Cooking water was retained and weighed. The cooked legumes were ground into homogeneous samples for subsequent analyses. A grinder with stainless steel blades was used to minimize metal contamination. At each step of the procedure, care was taken to prevent contamination of the samples so that accurate data could be obtained. No ingredients, such as salt or baking soda, were added to the legumes during the cooking and sampling procedures.

Each sample of raw or cooked legume or cooking water was analyzed for moisture, nitrogen, ash, fat, and crude fiber by official methods of the AOAC (1970). In addition,

Table I. Preparation and Yield of Product for Ten Kinds of Mature Dry Legumes[a]

Kind of legume	Preparation data[b]			Cooked legumes, yield from 1 cup dry legumes			Cooked wt/dry wt
	Wt/cup of dry legume, g	Water added, g	Cooking time, min	Wt, g	Vol, cups	Water absorbed, g	
Phaseolus vulgaris							
Navy beans	208	984 ± 22	75	469 ± 2	2.4 ± 0.01	261 ± 2	2.25
Great northern beans	209	928 ± 8	75	537 ± 1	3.0 ± 0	328 ± 1	2.57
Pinto beans	226	952 ± 10	90	539 ± 1	2.6 ± 0	313 ± 1	2.38
Red kidney beans	195	921 ± 7	90	473 ± 4	2.6 ± 0.02	278 ± 4	2.42
Phaseolus limensis							
Baby lima beans	215	921 ± 9	60	506 ± 3	2.6 ± 0	291 ± 3	2.35
Large lima beans	209	922 ± 9	60	546 ± 5	2.9 ± 0.07	337 ± 5	2.61
Vigna unguiculata (L.) Walp							
Cowpeas (blackeyes)	213	941 ± 7	30	592 ± 2	2.9 ± 0.07	379 ± 2	2.78
Cicer arietinum L.							
Chickpeas	229	1175 ± 4	140	474 ± 1	2.8 ± 0	245 ± 1	2.07
Pisum sativum L.							
Green split peas	217	911 ± 7	20	545 ± 4	2.3 ± 0	328 ± 4	2.51
Lens culinaris Medic							
Lentils, split, without seed coat	204	914 ± 10	30	600 ± 2	3.2 ± 0.07	396 ± 2	2.94

[a] Each value represents the mean of two samples from each of three different lots. Standard errors are reported where appropriate. [b] For preparation procedures, see text.

cooking water was analyzed for moisture, nitrogen, and ash by the same methods. 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).

RESULTS AND DISCUSSION

Preparation data and yields, both weight and volume, for cooked legumes are given in Table I. Weights per cup of dry legumes ranged from 195 g for red kidney beans to 229 g for chickpeas. Weights per cup were higher than average values previously reported per cup of uncooked dry legumes (Dawson et al., 1969). In fact, for five of the legumes—Great Northern and pinto beans, baby and large lima beans, and chickpeas—average cup weights reported in Table I are three standard deviations higher than Dawson's values. The reasons for these differences are not known. Lot-to-lot variations in the sizes of dry legumes and the extent to which the cup was packed in measuring could contribute to the differences. It is possible that the greater weight of legumes per cup as found in this study than in Dawson's report explains why it was necessary to use more water in cooking. Water added to the legumes for cooking ranged from 911 to 1175 g for green split peas and chickpeas, and cooking time ranged from 20 min for green split peas to 140 min for chickpeas.

Of the dry legumes, uncooked chickpeas weighed the most per cup, had the greatest weight of water added, and were cooked for the longest time of any of the legumes. However, the water absorbed with cooking of 1 cup of chickpeas, 245 g, was less than that absorbed with cooking of the other legumes. Absorbed water for the other legumes ranged from 261 g for navy beans to 396 g for lentils. The firm texture and round shape of chickpeas may slow down absorption of water, thus lengthening the cooking time required to yield a tender product.

The ratio of cooked weight to dry weight was considerably lower for cooked chickpeas, 2.07, than for the other legumes, for which ratios ranged from 2.25 to 2.94. In contrast, lentils, which weighed the least per cup of dry legume, 204 g, were the highest in weight after cooking, 600 g, absorbed the greatest weight of water, 396 g (compared with a range of 245 to 379 g for other legumes), and had the largest ratio for cooked weight to dry weight, 2.94.

Yield values obtained from this work were used in deriving representative values for yields of cooked legumes for the revision of USDA tables on yields of foods (Matthews and Garrison, 1975). Data from the present research were found by Matthews (personal communication) to be in close agreement with other available data on yields of legumes as currently marketed and cooked.

Data on proximate composition (moisture, protein, fat, total carbohydrate, crude fiber, and ash) and food energy values are given for raw and cooked legumes in Table II. Moisture values for uncooked legumes were generally higher than previously published data (deMoraes and Angelucci, 1971; Watt and Merrill, 1963; Kuzayli et al., 1966; Kadwe et al., 1974). Only large lima beans, with a value of 8.9%, were lower in moisture content than the value (10.3%) given in Handbook 8. California dry beans normally contain 9 to 12% moisture (California Dry Bean Advisory Board, 1975). The origins of the samples reported in Table II are not known, but average moisture values exceeded 12% for all legumes but large lima beans. According to Wagner (1975), the moisture content of dried legumes is greatly affected by relative humidity of the surrounding atmosphere at harvest and during storage. The differences in moisture content between the data reported in Table II and data from other sources may well have been due to past environments and sources of the samples. Three lots of legumes purchased in retail in one locality would not necessarily be representative of the moisture content of the same kinds of legumes stored and marketed in other localities.

Protein, fat, and ash values determined for the samples in our study were generally in good agreement with, but slightly lower than, data tabulated in Handbook 8. These slightly lower values might be partly explained by the higher moisture values found in the current research. Data for protein, fat, and ash were in reasonably good agreement with ash values reported by deMoraes and Angelucci (1971), Kuzayli et al. (1966), Kadwe et al. (1974), and Sinha and Tripathi (1973). Our data, when compared with values reported by the California Dry Bean Advisory Board (1975), showed protein to be higher and fat and ash lower

Table II. Proximate Composition of Raw and Cooked Mature Dry Legumes[a]

Kind of legume	Moisture (g/100 g)	Food energy[b]	Protein (N × 6.25)	Fat	Carbohydrate: Total[b] (by difference)	Carbohydrate: Crude fiber	Ash
Raw legumes							
Phaseolus vulgaris							
Navy beans	18.2 ± 0.5	315	21.1 ± 0.1	1.5 ± 0.04	56.3	6.6 ± 0.1	2.9 ± 0.01
Great northern beans	13.3 ± 0.4	330	21.0 ± 0.1	1.0 ± 0.02	61.2	6.7 ± 0.1	3.5 ± 0.05
Pinto beans	14.7 ± 0.6	327	18.8 ± 0.3	1.2 ± 0.02	61.8	6.3 ± 0.2	3.5 ± 0.03
Red kidney beans	12.7 ± 0.6	335	21.5 ± 0.2	1.1 ± 0.02	61.7	7.0 ± 0.1	3.0 ± 0.01
Signif. of diff.[c]	**		**	**		**	**
LSD[c]	2.1		0.8	0.1		0.5	0.2
Phaseolus limensis							
Baby lima beans	13.3 ± 0.2	330	20.4 ± 0.2	0.8 ± 0.01	62.1	6.0 ± 0.1	3.4 ± 0.03
Large lima beans	8.9 ± 0.3	344	22.3 ± 0.3	0.8 ± 0.01	63.8	7.4 ± 0.2	4.2 ± 0.08
Signif. of diff.[c]	**		**	NS		**	**
Vigna unguiculata (L.) Walp							
Cowpeas (blackeyes)	16 2 ± 1.2	321	21.2 ± 0.1	1.3 ± 0.03	58.2	6.0 ± 0.1	3.1 ± 0.08
Cicer arietinum L.							
Chickpeas	18.6 ± 0.7	334	17.8 ± 0.4	5.0 ± 0.17	56.7	4.0 ± 0.1	1.9 ± 0.03
Pisum sativum L.							
Green split peas	15.5 ± 0.6	326	21.0 ± 0.2	1.0 ± 0.03	60.1	3.3 ± 0.0	2.4 ± 0.06
Lens culinaris Medic							
Lentils, split, without seed coat	14.2 ± 0.7	326	26.4 ± 0.3	0.8 ± 0.04	56.0	6.1 ± 0.1	2.6 ± 0.05
Cooked legumes							
Phaseolus vulgaris							
Navy beans	63.1 ± 1.7	143	8.9 ± 0.2	0.6 ± 0.01	26.2	3.1 ± 0.1	1.2 ± 0.06
Great northern beans	67.8 ± 0.3	123	8.2 ± 0.1	0.4 ± 0.01	22.5	3.0 ± 0.1	1.1 ± 0.03
Pinto beans	65.9 ± 0.6	131	7.7 ± 0.1	0.5 ± 0.02	24.5	3.0 ± 0.1	1.4 ± 0.04
Red kidney beans	67.1 ± 0.2	127	8.3 ± 0.1	0.5 ± 0.01	23.1	2.9 ± 0.1	1.0 ± 0.04
Signif. of diff.[c]	**		**	**		NS	**
LSD[c]	3.6		0.6	0.05			0.2
Phaseolus limensis							
Baby lima beans	69.5 ± 0.3	117	7.6 ± 0.1	0.4 ± 0.02	21.5	3.7 ± 0.1	1.0 ± 0.03
Large lima beans	71.0 ± 0.1	110	7.7 ± 0.1	0.3 ± 0.01	19.9	3.3 ± 0.1	1.1 ± 0.02
Signif. of diff.[c]	**		NS	*		**	**
Vigna unguiculata (L.) Walp							
Cowpeas (blackeyes)	71.9 ± 0.4	109	7.4 ± 0.1	0.5 ± 0.01	19.4	2.4 ± 0.1	0.8 ± 0.01
Cicer arietinum L.							
Chickpeas	58.1 ± 0.2	171	9.4 ± 0.2	2.3 ± 0 06	29.3	2.6 ± 0.1	0.9 ± 0.02
Pisum sativum L.							
Green split peas	70.7 ± 0.4	114	7.4 ± 0.1	0.3 ± 0.01	21.0	2.0 ± 0.1	0.6 ± 0.02
Lens culinaris Medic:							
Lentils, split, without seed coat	72.5 ± 0.3	106	8.7 ± 0.2	0.4 ± 0.01	17.7	2.8 ± 0.0	0.7 ± 0.02

[a] Each value is the mean ± standard error of four analyses from each of three purchase lots (N = 12). [b] Calculated values. Standard errors and significance of differences not determined. [c] Significance of differences: *, $P = 0.05$; **, $P = 0.01$. Least significant difference (LSD) is for the specified level of significance. Two sample means are from different populations if the difference between those sample means exceeds the value of the LSD.

for raw large lima beans. Protein, fat, and ash in raw cowpeas were in good agreement for the two studies.

In contrast to the generally good agreement between data from this research and from other sources for protein, fat, and ash contents, values reported here for crude fiber were higher than crude fiber values reported in Handbook 8, by the California Dry Bean Advisory Board (1975), and by deMoraes and Angelucci (1971), but were in fairly good agreement with Kuzayli et al. (1966). Data from the two last-named sources are from samples of foreign origin. Data for crude fiber in Handbook 8 relied heavily on studies made in Central and South America, and on values published before 1930. Whether the higher values for crude fiber in the current American market samples reported here represent true differences from data from other sources (rather than interlaboratory variation in the use of a highly empirical method of analysis or seasonal and location variations) cannot be determined from the data at hand. The California data indicate that legumes as currently marketed are not necessarily higher in fiber than in the past. Further analyses for crude fiber, on dry legumes obtained from different sources, would be helpful.

Variations among lots of a raw legume are shown by the standard errors reported in Table II for each of the proximate components which were determined by laboratory analysis. As results of duplicate analyses for the same brand or market lot of any one legume were in remarkably good agreement, the variation shown by the standard errors is primarily caused by differences among brands. These differences, while not great, tended to be higher for moisture than for other proximate components. Moisture differences, as previously pointed out, may be caused by past environments and sources of the samples.

Data for proximate composition of cooked legumes are also given in Table II. Data for protein, fat, and ash are generally in good agreement with data for these components as given in Handbook 8. Data for moisture in cooked *Phaseolus vulgaris* beans and cowpeas were lower, and

Table III. Yield and Composition of Water Drained after Cooking Ten Kinds of Dry Mature Legumes[a]

Kind of legume	Water drained after cooking 1 cup of dry legumes[a]		Proximate composition,[b] g/100 g			
	Wt, g	Volume, c.	Moisture	Protein (N × 6.25)	Ash[c]	Other[d]
Phaseolus vulgaris						
Navy beans	130 ± 26	0.6 ± 0.15	90.9 ± 0.6	2.8 ± 0.1	0.14 ± 0.01	6.2
Great northern beans	134 ± 15	0.7 ± 0.03	93.3 ± 0.2	1.6 ± 0.1	0.09 ± 0.00	5.0
Pinto beans	88 ± 8	0.4 ± 0.03	86.8 ± 0.3	2.6 ± 0.1	0.13 ± 0.01	10.5
Red kidney beans	171 ± 11	0.8 ± 0.07	91.5 ± 0.4	1.8 ± 0.1	0.07 ± 0.00	6.6
Signif. of diff.[e]	NS	NS	**	**	**	
LSD[e]			1.5	0.4	0.02	
Phaseolus limensis						
Baby lima beans	252 ± 10	1.1 ± 0.02	89.1 ± 0.6	2.5 ± 0.2	0.08 ± 0.01	8.3
Large lima beans	277 ± 23	1.2 ± 0.09	90.0 ± 0 8	1.6 ± 0.1	0.10 ± 0.00	8.3
Signif. of diff.[e]	NS	NS	NS	**	*	
Vigna unguiculata (L.) Walp						
Cowpeas (blackeyes)	362 ± 11	1.6 ± 0.03	93.6 ± 0.7	1.2 ± 0.2	0.06 ± 0.00	5.1
Cicer arietinum L.						
Chickpeas	107 ± 8	0.5 ± 0.03	91.3 ± 0.3	1.6 ± 0.1	0.07 ± 0.00	7.0
Pisum sativum L.						
Green split peas	402 ± 5	1.7 ± 0	94.3 ± 0.6	2.0 ± 0.1	0.04 ± 0.00	3.7
Lens culinaris Medic						
Lentils, split, without seed coat	281 ± 11	1.3 ± 0.08	94.0 ± 0.4	2.2 ± 0.1	0.06 ± 0.00	3.7

[a] Each value is the mean ± standared error of two values from each of three lots. Procedures for draining legumes and weighing and measuring drained liquid are given in text. [b] Each value is the mean ± standard error of four values from each of three lots. [c] Data are given to two decimal places to show that values less than 0.1 g/100 g are greater than 0. [d] Primarily carbohydrate. Calculated by difference. [e] Significance of differences: *, $P = 0.05$; **, $P = 0.01$. Least significant difference is for the specified level of significance. Two sample means are from different populations if the difference between those sample means exceeds the value of the LSD.

data for moisture in baby and large lima beans were higher than comparable values for Handbook 8. Values for crude fiber in cooked legumes, as for raw legumes, were higher than values for comparable samples in Handbook 8. Comparisons between data in Table II and data from California (California Dry Bean Advisory Board, 1975) on cooked large lima beans and cooked cowpeas show reasonable agreement for content of protein, fat, and ash. Fiber values, however, were considerably higher in the present study than in the California data.

Analyses of variance showed significant differences (1% level) among four kinds of beans bearing the scientific name *Phaseolus vulgaris* for all proximate components except fiber in cooked beans. Least significant differences (LSD's) given in Table II can be used to determine which of the values were significantly different from each other. The LSD's show that raw navy beans were significantly higher in moisture and fat than the three other raw *P. vulgaris* beans. Pinto beans were lower in protein than the three other beans, and were also significantly lower in crude fiber than red kidney beans. Navy and kidney beans contained significantly less ash than Great Northern and pinto beans. For cooked *Phaseolus vulgaris* beans, navy beans contained significantly less moisture and more protein and fat than did the other three kinds of beans. Cooked pinto beans were higher in ash than navy, Great Northern, or red kidney beans. Crude fiber contents did not differ significantly among the four kinds of cooked *P. vulgaris* beans.

Analyses of variance for baby and large lima beans show that raw large lima beans were significantly lower in moisture content and higher in content of protein, crude fiber, and ash than baby lima beans. Although significant differences were found between cooked baby and large lima beans, these differences were small and would not be nutritionally important.

Table III contains data on yields in weight and volume, and proximate composition of cooking water remaining when different kinds of legumes were cooked. The cooking water was primarily moisture; moisture content ranged from 87% in pinto beans to 94% in lentils, green split peas, and cowpeas. Cooking water also contained about 1 to 3% protein, a small amount of ash, and 4 to 10% of other material, probably primarily carbohydrate. The presence of these solids in the cooking water is evidence that retentions of nutrients in cooked legumes should not be calculated by first converting data to the moisture-free basis and ignoring weights of legumes before and after cooking, as the solids contents of the raw and cooked samples are not comparable, and the proportion of solids lost to the cooking water may be different from the proportion of a nutrient so lost.

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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.

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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).