Nutritional and health benefits of dried beans[1–3]

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ABSTRACT

Dried beans (often referred to as grain legumes) may contribute to some of the health benefits associated with plant-based diets. Beans are rich in a number of important micronutrients, including potassium, magnesium, folate, iron, and zinc, and are important sources of protein in vegetarian diets. In particular, they are among the only plant foods that provide significant amounts of the indispensable amino acid lysine. Commonly consumed dried beans are also rich in total and soluble fiber as well as in resistant starch, all of which contribute to the low glycemic index of these foods. They also provide ample amounts of polyphenols, many of which are potent antioxidants. Intervention and prospective research suggests that diets that include beans reduce low-density lipoprotein cholesterol, favorably affect risk factors for metabolic syndrome, and reduce risk of ischemic heart disease and diabetes. The relatively low bean intakes of North Americans and northern Europeans can be attributed to a negative culinary image as well as to intestinal discomfort attributable to the oligosaccharide content of beans. Cooking practices such as sprouting beans, soaking and discarding soaking water before cooking, and cooking in water with a more alkaline pH can reduce oligosaccharide content. Promotional efforts are needed to increase bean intake. *Am J Clin Nutr* 2014;100(suppl):437S–42S.

INTRODUCTION

Dried beans play a prominent role in the diets of many vegetarians and may contribute to some of the health benefits associated with this eating pattern (1). Their health benefits derive from direct attributes, such as their low saturated fat content and high content of essential nutrients and phytochemicals, as well as to displacement effects when they are substituted for animal products in the diet.

This article addresses the nutritional and health attributes of common dried beans, such as kidney, pinto, navy, lima beans, and adzuki beans, and chickpeas and lentils, foods that the FAO defines as grain legumes or pulses. This definition excludes the oil-producing legumes such as soybeans and peanuts and legumes that are harvested as vegetables such as common garden peas (2).

BEAN CONSUMPTION PATTERNS

Beans are an important source of protein in developing countries. Because populations in recent decades have adopted more Western-style diets, however, dried bean consumption has seen a decline. For example, between the 1960s and 1990s, dried bean intake decreased by 40% in India and by 24% in Mexico (3).

Dried beans are greatly underutilized by North Americans (4) and northern Europeans (5). On any given day, <8% of Americans reported consuming beans according to 1999–2002 NHANES data (4). Unfortunately, despite acknowledging their nutritional advantages, the US government does relatively little to encourage bean intake. In fact, the Dietary Guidelines Advisory Committee (DGAC)[4] decreased bean and pea intake recommendations from 3 cups/wk in 2005 to 1.5 cups/wk in 2010 (6). (The DGAC considers beans and peas to include kidney beans, pinto beans, black beans, chickpeas, lima beans, black eye peas, split peas, and lentils.)

In the United States, there is considerable variation in bean consumption among ethnic groups with the highest consumption seen among Hispanics, 25% of whom consume beans daily (4). Consumption also appears to follow income and is higher at lower income levels, although this relation may reflect ethnicity to some extent. Among US men aged ≥20 y, the frequency of bean intake during a 3-d period between 1989 and 1991 was 36.3%, 32.3%, and 25.7% among those with incomes <131%, 131–350%, and >350% of the federal poverty level, respectively (7). Findings from the Continuing Survey of Food Intakes by Individuals 1994–1996 indicated that 14% of Americans consumed at least one food containing dried beans during a 2-d period (8). Not surprisingly, dried bean intake is higher among vegetarians than nonvegetarians, although only limited data are available. For example, according to the survey, <1% of meat eaters consumed lentils or garbanzo beans on at least one recall day, whereas ∼10% of vegetarians did (1).

NUTRIENT CONTENT

Beans contribute a number of important micronutrients to diets (**Table 1**). According to NHANES 1999–2002 data, relative to nonconsumers, those in the fourth bean intake quartile (mean intake: 277.1 g/d) consumed 31%, 22%, 13%, and 12% more folate, iron, zinc, and magnesium, respectively (4). Beans are also rich in potassium, a mineral identified as a nutrient of concern by the DGAC. US adult men and women consume only

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[4] Abbreviations used: CVD, cardiovascular disease; DGAC, Dietary Guidelines Advisory Committee; GI, glycemic index; Hb A_{1c}, glycated hemoglobin; IHD, ischemic heart disease; PI, protease inhibitor; RDA, Recommended Dietary Allowance; RS, resistant starch.

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TABLE 1
Nutrient content of selected dried beans[1]

Bean (weight in g per 0.5 cup cooked beans)	Protein	Iron	Zinc	Calcium	Potassium	Magnesium	Folate
	g	*mg*	*mg*	*mg*	*mg*	*mg*	*μg*
Adzuki beans (115 g)	8.6	2.3	2.0	32	611	60	140
Black beans (86 g)	7.6	1.8	0.96	23	305	60	128
Chickpeas (82 g)	7.5	2.4	1.2	40	239	39	141
Great northern beans (88.5 g)	7.4	1.9	0.78	60	346	44	90
Kidney beans (88.5 g)	7.7	2.0	0.9	31	358	37	115
Lentils (99 g)	8.9	3.3	1.3	19	365	35	179
Lima beans (94 g)	7.3	2.25	0.9	16	478	40	78
Navy beans (85.5 g)	7.5	2.15	0.9	63	354	48	127
Pinto beans (85.5 g)	7.7	1.8	0.8	40	373	43	147

[1] Data from reference 9.

approximately two-thirds and one-half of the Recommended Dietary Allowance (RDA) for this nutrient, respectively (10). One serving of beans contains between 300 and 400 mg potassium, which is similar to that provided by one serving of cow milk. Interestingly, the DGAC noted that it would be difficult to reach the recommended potassium intake without 3 daily servings of dairy, a conclusion that reflects the degree to which beans are not commonly consumed in the United States, because they were not given a similar mention (11).

Beans are unique among protein-rich foods for their high carbohydrate and low fat content. Approximately 3% of kilocalories in beans derive from fat, most of which is unsaturated. Chickpeas are an exception, providing ∼15% of energy as fat. On a caloric basis, the protein content of beans is generally between 20% and 30%. A serving of beans (∼90 g or 0.5 cup cooked beans) provides 7–8 g protein. However, it is the indispensable amino acid lysine rather than the total protein content of beans that is a more important consideration for people consuming plant-based diets. Diets based on plant foods may fall short of meeting lysine needs if beans or other legumes (peanuts or soy) are not included in menus. One-half cup of beans provides only ∼16% of the total protein requirement for a 60-kg person but 25% of the total lysine requirement (**Table 2**).

TABLE 2
Protein and lysine contents of selected dried beans, tubers, and grains[1]

Food (weight in g per 0.5 cup cooked food)	Total protein per 0.5-cup serving	Total lysine per 0.5-cup serving
	g	*mg*
Black beans (86 g)	7.6	523
Brown rice (97.5 g)	2.5	96.5
Chickpeas (82 g)	7.25	486
Great northern beans (88.5 g)	7.3	506
Kidney beans (88.5 g)	7.7	537
Lentils (99 g)	8.93	624
Lima beans (94 g)	7.3	492
Navy beans (91 g)	7.5	473
Pinto beans (85 g)	7.7	538
Sweet potato (164 g)	2.25	95
Tempeh (83 g)	15	750
Tofu, firm (126 g)	19.9	1309
White potato (78 g)	1.46	155

[1] Data from reference 9.

The lysine content of beans is especially notable because food processing can cause lysine to be modified in a way that makes it unavailable for protein synthesis, an issue recognized by the newly released FAO report on dietary protein quality (12).

RESISTANT STARCH AND FIBER

Beans are especially high in resistant starch (RS), generally defined as starch and products of starch degradation not digested in the small intestine (13, 14). The RS content of beans is much higher than in commonly consumed grains, most likely because of their high ratio of amylose to amylopectin (**Table 3**); amylose is a nonbranched, linear polymer of glucose units that is less readily digested than amylopectin (15)

Beans are also rich in fiber, even compared with other unrefined plant foods. One-half cup of beans provides between 5.2 and 7.8 g of total fiber compared with ∼1.7–4 g of fiber per a 0.5-cup serving of whole grains (**Table 4**). They are also among the best sources of soluble fiber (16). According to the National Cholesterol Education Program, 5–10 g soluble fiber/d reduces LDL cholesterol by ∼5% (17). One-half cup of beans provides between 0.6 and 2.4 g soluble fiber (18).

Beans generally have a low glycemic index (GI) compared with other carbohydrate-rich foods, likely a result of both their RS and fiber content (19). The GI of beans ranges from 29 to 38 compared with 50 for brown rice and 55 for rolled oats (19). The low GI of beans can potentially produce clinically relevant

TABLE 3
Resistant starch content of selected legumes and grains[1]

Food	Resistant starch
	g/100 g cooked food
Black beans	1.7
Chickpeas	2.6
Kidney beans	2.0
Lentils	3.4
Navy beans	4.2
Pinto beans	1.9
Barley, pearled	2.4
Bran flakes	0.7
Oatmeal	0.2
Pasta, whole wheat	1.4

[1] Adapted from reference 14.

TABLE 4
Total fiber content of selected legumes[1]

Legume (weight in g per 0.5 cup cooked legumes)	Total fiber
	g
Black beans (86 g)	7.5
Chickpeas (82 g)	6.2
Great northern beans (88.5 g)	6.2
Kidney beans (88.5 g)	5.7
Lentils (99 g)	7.8
Lima beans (94 g)	6.6
Navy beans (91 g)	5.2
Pinto beans (85.5 g)	7.7

[1] Data from reference 9.

benefits. For example, when study participants with diabetes were instructed to increase their legume intake by at least 1 cup/d, glycated hemoglobin (Hb A_{1c}) values decreased by 0.5% compared with a decrease of 0.3% (difference between treatments, $P < 0.001$) in response to supplementation with wheat fiber (20). Changes in Hb A_{1c} concentrations of as little as 1% are associated with as much as a 15–18% reduced risk of ischemic heart disease (IHD) in people with diabetes (21).

NONNUTRIENT CONTENT

Beans contain a number of polyphenolic compounds (tannins, phenolic acids, and flavonoids) that may confer a variety of health benefits. As noted, many polyphenols are potent antioxidants, so it is not surprising that in an analysis of 25 different types of beans, total antioxidant activity correlated directly with their polyphenol content (22).

Beans also contain several compounds that traditionally have been classified as antinutrients, which are compounds that can interfere with the digestion and utilization of nutrients. These include protease inhibitors (PIs), lectins, phytates, and oxalates (23, 24). However, it is important to recognize that the effects of individual components studied in isolation may not predict effects when these components are consumed in a mixture as normally occurs in the diet (25). Furthermore, over the past 20 y, the scientific community has recognized that some antinutrients may actually impart health benefits.

Antinutrients are found throughout the plant kingdom, but foods containing them can be safely consumed because conventional food processing greatly reduces their concentrations and/or because harmful effects occur only after consuming excessive amounts. Beans can be especially high in lectins and PIs. Lectins are plant proteins possessing at least one noncatalytic domain, which bind reversibly to a specific mono- or oligosaccharide. Orally ingested plant lectins remaining at least partially undigested in the gut may bind to a wide variety of cell membranes and glycoconjugates of the intestinal and colonic mucosa, leading to various deleterious effects on the mucosa itself as well as on the intestinal bacterial flora and other inner organs (26, 27). However, high temperatures using moist heat can inactivate most lectins (28).

This treatment also applies to PIs; consequently, the PI content of properly cooked beans likely has little impact on protein digestion (29). Boiling dried beans reduces trypsin inhibitor content by 80–90% (30). However, other components such as fiber likely contribute to the somewhat lower protein digestibility of beans in comparison to the digestion of protein from animal foods (31).

Mineral absorption is adversely affected by both phytates and oxalates, although the latter affects primarily only calcium. Fractional calcium absorption from beans ranges from 22% for white beans to almost 27% for pinto beans compared with 30% for fortified soy milk and up to 61% for low-oxalate vegetables such as broccoli (32). Because beans are relatively low in total calcium, they are likely to make only minor contributions to calcium intake. However, the consumption of beans by those following a low-oxalate diet as a means of preventing the development or recurrence of kidney stones, ~80% of which are composed of calcium oxalates, needs to be carefully considered. Chai and Liebman (33) found that there was a wide range (4–80 mg/100 g) of oxalate content of cooked dried beans. Dried beans containing low amounts of total oxalate include green split peas, yellow split peas, and black-eyed peas.

The phytate content of beans ranges from ~0.1% to 2% (24, 34). Phytate is not destroyed by heat, so it is an important factor affecting mineral absorption from beans, especially for minerals such as zinc, which tends to be low in plant-based diets. Soaking and fermentation may reduce the effects of phytate and increase zinc absorption (35). Phytate also reduces the absorption of iron from beans and other plant foods, which is one reason the vegetarian RDA for iron is 1.8 times higher than the nonvegetarian RDA. However, variable amounts of iron in beans are present in the storage form ferritin. In white beans, for example, as much as 90% of the total iron is in the form of ferritin or other soluble iron (36). Ferritin may be resistant to traditional inhibitors of iron absorption and therefore much better absorbed than generally thought (37), although findings are conflicting because it is unclear as to how much ferritin survives cooking and digestion (38). Phytate is an example of an antinutrient that may exert beneficial effects. It is an antioxidant (39) that may reduce the risk of certain cancers (40) and kidney stones (41).

PROPOSED HEALTH BENEFITS

Glycemic control and diabetes

Clinical studies consistently show that when replacing other carbohydrate-rich foods, beans reduce postprandial glucose elevations in both diabetic and nondiabetic participants (19, 42, 43). In a meta-analysis of 41 clinical studies, pulses alone (11 trials) lowered (standardized mean difference; 95% CI) fasting blood glucose (−0.82; −1.36, −0.27) and insulin (0.49; 0.93, −0.04) concentrations; pulses in low-GI diets (19 trials) lowered glycosylated blood proteins, measured as Hb A_{1c} or fructosamine (−0.28; −0.42, −0.14); and pulses in high-fiber diets (11 trials) lowered fasting blood glucose (−0.32; −0.49, −0.15) and glycosylated blood proteins (0.27; −0.45, −0.09) (44). Consistent with these findings are those from the Shanghai Women's Health Study, a prospective epidemiologic study in 64,000 middle-aged women who were followed for 4.5 y (45). When comparing extreme quintiles, bean (a category that excludes peanuts and soy products) intake was associated with a significant decreased risk of developing diabetes (RR: 0.76; 95% CI: 0.64, 0.90). Properties of beans possibly contributing to the effects on glycemic control include their low GI, high fiber content, and possibly their polyphenol content, which may protect against the development of type 2 diabetes through their antioxidant effects (46). The RS content of beans may also be a key factor because intakes of as low as 6–12 g at a meal were shown to favorably affect postprandial glucose and insulin concentrations (15, 47). For example, in a study in 9 normal and 9 overweight participants, the plasma glucose concentration at 30 min after a meal containing 6.5 g RS was 8.04 mmol/L, which was significantly lower than the 8.92 mmol/L concentration in response to the same meal containing only 0.9 g RS (48).

Metabolic syndrome

Two meta-analyses of randomized controlled trials found that bean consumption (2–5 cups/wk for 3–12 wk) favorably affected risk factors for metabolic syndrome (44, 49). More recently, regularly consuming beans (5 cups/wk) ad libitum was shown to be as effective at reducing variables associated with the metabolic syndrome among a small group of overweight and obese middle-aged men and women as an energy-restricted diet achieved through counseling. Both the bean and energy-restricted diets led to decreases in energy intake, waist circumference, systolic blood pressure, and Hb A_{1c} and to improvements in blood glucose control and insulin sensitivity. The bean diet alone was also effective in increasing HDL-cholesterol concentrations (50).

IHD

Several lines of evidence suggest that bean intake reduces the risk of IHD. For example, in the NHANES I Epidemiologic Follow-Up Study, a prospective investigation in nearly 10,000 men and women, bean intake was associated with a reduced risk of both IHD and cardiovascular disease (CVD). More specifically, when comparing the fourth (≥4 times/wk) with the first intake quartile, the RRs (95% CI) were 0.78 (0.68, 0.90) for IHD and 0.91 (0.80, 0.98) for CVD (51). A limitation of this study, however, was that legume intake appeared to include peanut and possibly soy products, although soy products are consumed in negligible amounts in Western populations.

Coronary benefits of beans are likely at least partially attributable to their hypocholesterolemic properties (52–54). In a meta-analysis of 9 intervention studies with a total of 238 participants, bean consumption (intervention typically consisted of ∼120 g/d) resulted in a mean decrease (95% CI) of 8.0 mg/dL (−11.4, −4.6 mg/dL) in LDL cholesterol without affecting HDL cholesterol (49). Cholesterol reduction likely results from the high soluble fiber content of beans, which is thought to reduce LDL cholesterol (55) by increasing bile acid excretion (16). In addition, colonic fermentation of soluble fiber produces short-chain fatty acids such as propionate, which may decrease hepatic cholesterol synthesis, thereby also decreasing circulating LDL-cholesterol concentrations (56, 57).

Australian researchers found that simply asking subjects to add ≥4 cans of chickpeas/wk to their diet (without providing any additional dietary instruction) increased fiber intake (by 7 g/d) and decreased LDL cholesterol (by 7.3 mg/dL) (58). Although caloric intake was slightly higher during the chickpea phase, the participants lost a small amount of body weight during this phase.

Finally, bean consumption may decrease CVD as well as other diseases by reducing inflammation. Although data are very limited, there are both clinical (59) and epidemiologic data showing that bean intake reduces C-reactive protein concentrations (60).

Mortality

Bean consumption has been associated with reduced risk of mortality, although only limited data on this endpoint are available. The Food Habits in Later Life Study followed nearly 800 older men and women for 7 y, during which time 169 participants died (61). Among the 5 populations evaluated, mean legume intake ranged from ∼85 g/d in Japan and Greece to a low of only 14 g/d in some segments of the Australian population. Of all of the food groups studied, legumes were the only foods associated with a reduced risk of mortality: the RR was 0.92 (95% CI: 0.85, 0.99) for every 20 g consumed. Dried beans were not assessed separately in this study, although other than in Japan, soybean intake would be negligible among the populations in this survey.

Cancer

Evidence that suggests that bean intake reduces cancer risk is unimpressive. In their 2007 review of the literature, the American Institute for Cancer Research found only limited evidence that suggested protection against just 2 cancers—stomach and prostate—with most of the protection being attributable to soy foods (62). Studies of other cancers failed to find associations between bean intake and risk. Nevertheless, worthy of note are the results of an older and relatively small prospective study that suggests that bean intake may reduce pancreatic cancer risk (63). Among the 34,000 Seventh-day Adventists who were followed for 6 y, the RR (95% CI) in those who consumed beans (beans, lentils, and peas) ≥3/wk was 0.43 (0.16, 1.13; P-trend = 0.044) for fatal pancreatic cancer; furthermore, this value was 0.03 (0.003, 0.24) after adjustment for multiple variables. Bean intake was also associated with a lower risk of colorectal polyps in the Adventist Health Study (foods in the legume category were not specified) (64), the Nurses' Health Study (foods included beans, lentils, peas, lima beans, tofu, and soybeans) (65), and the Polyp Prevention Trial (beans were defined as cooked dry beans, such as pinto and navy beans, lentils, and bean soups, but not green beans or green peas) (66), although, as can be seen, foods included in the bean category differed between the studies and in some cases extended beyond dried beans.

CONSUMER ISSUES

Bean consumption appears to be associated with a number of advantages unrelated to health. For example, the replacement of meat and other animal products with beans is associated with reductions in inputs of environmental resources and with improved animal welfare (67). Beans also serve as an economical source of nutrients. The Median Nutrient Rich Foods Index Score, which ranks foods on the basis of their cost per 100 calories and their nutrient value, found that beans, nuts, and seeds provided the highest nutrient value for the lowest cost (68). However, there are multiple barriers to bean consumption, including perceived inconvenience, a negative culinary image, and intestinal discomfort.

More than 50 y ago, diets containing beans were first shown to increase flatulence (69); and in 1970, oligosaccharides were shown to be responsible for the gas production (70). The oligosaccharide content of dried beans ranges from 25 to 50 mg/g (71). Despite the intestinal discomfort, there may be some benefits associated with oligosaccharide intake. Because of their growth-promoting effect on bifidobacteria, oligosaccharides have been hypothesized to promote the health of the colon, increase longevity, and decrease colon cancer risk (72).

The concomitant gas production associated with oligosaccharides intake can, however, act as a deterrent to bean consumption. Commercial products such as Beano (AkPharma Inc) are digestive aids that contain α-galactosidase and are available so that individuals can eat beans without discomfort. Food preparation practices can also reduce oligosaccharide content. Although some evidence suggests that soaking beans without discarding the soaking water has little effect on oligosaccharide content or increases amounts, either boiling unsoaked beans or soaking and then discarding soaking water before cooking has been shown to reduce oligosaccharide content up to 76% (73). Cooking beans in alkaline water reduces oligosaccharide content even further. Germinating beans has been shown to reduce amounts of these carbohydrates as well (73).

CONCLUSIONS

Beans are excellent sources of protein and a number of micronutrients, some of which fall short in Western diets. They are also rich in fiber and RS, which may account for some of their proposed health benefits. Although beans play important roles in many diets throughout the world, they remain underutilized in North America and northern Europe. Given their health and nutritional benefits, health professionals should make a concerted effort to encourage greater bean consumption.

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