Pulse Consumption, Satiety, and Weight Management

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ABSTRACT

The prevalence of obesity has reached epidemic proportions, making finding effective solutions to reduce obesity a public health priority. One part of the solution could be for individuals to increase consumption of nonoilseed pulses (dry beans, peas, chickpeas, and lentils), because they have nutritional attributes thought to benefit weight control, including slowly digestible carbohydrates, high fiber and protein contents, and moderate energy density. Observational studies consistently show an inverse relationship between pulse consumption and BMI or risk for obesity, but many do not control for potentially confounding dietary and other lifestyle factors. Short-term (≤1 d) experimental studies using meals controlled for energy, but not those controlled for available carbohydrate, show that pulse consumption increases satiety over 2–4 h, suggesting that at least part of the effect of pulses on satiety is mediated by available carbohydrate amount or composition. Randomized controlled trials generally support a beneficial effect of pulses on weight loss when pulse consumption is coupled with energy restriction, but not without energy restriction. However, few randomized trials have been conducted and most were short term (3–8 wk for whole pulses and 4–12 wk for pulse extracts). Overall, there is some indication of a beneficial effect of pulses on short-term satiety and weight loss during intentional energy restriction, but more studies are needed in this area, particularly those that are longer term (≥1 yr), investigate the optimal amount of pulses to consume for weight control, and include behavioral elements to help overcome barriers to pulse consumption. Adv. Nutr. 1: 17–30, 2010.

Introduction

The worldwide prevalence of obesity has reached epidemic proportions (1). Because excess body fat is associated with the development of life-threatening chronic conditions such as heart disease, type 2 diabetes, and certain types of cancer (2,3), viable and sustainable solutions for sustainable weight loss and prevention of weight gain are urgently needed. Generally, selection of a diet high in fiber, low in energy density and glycemic load, and moderate in protein is thought to be particularly important for weight control (4). Such a diet may be achieved by regularly consuming food from certain food groups, including fruits, vegetables, and whole grains; some lean meats, nuts, and legumes; and limited consumption of food from other groups, including high-fat meats, sugar-sweetened beverages, bakery items, and highly processed foods. In this review, we will focus of the role of legumes, particularly the nonoilseed pulses (see terminology below), in energy regulation and successful weight control, highlighting the work that has been published in the past 10 yr.

Terminology: legumes, pulses, and beans

The pods or fruits of plants in the botanical family Fabaceae, or Leguminosae, are commonly known as legumes. Legumes include alfalfa, clover, lupin, green beans and peas, peanuts, soybeans, dry beans, broad beans, dry peas, chickpeas, and lentils. According to the FAO (5), a pulse is a type of legume that is exclusively harvested for the dry grain and therefore excludes peanuts and soybeans, which are harvested for their oil. Pulses are also sometimes referred to as grain legumes or pulse grains. The published literature often refers to the Phaseolus vulgaris species; these include kidney beans, haricot beans, pinto beans, and navy beans. Figure 1 shows a simplified scheme of the classification of different legumes.

The health effects of soybeans and peanuts have been well studied. Although soybeans share some of the nutritional properties of pulses [e.g. high in fiber and protein, low glycemic index (GI)], they are thought to have unique health effects due to their high content of certain phytoestrogens such as isoflavones and other bioactive compounds (6). The effects of soybeans and soy protein (7–9) and peanuts (10–14) on body weight have been reviewed elsewhere and will not be covered here.

Macronutrient and phytochemical profiles of pulses and energy regulation

Pulses have a unique nutritional profile consistent with several dietary composition factors thought to assist with weight control. They also contain several antinutrients that have been suggested to play a role in energy regulation (Tables 1 and 2). In particular, they are high in fiber, providing ~7 g/0.5 c (120 mL) serving. Pulses...
are also relatively low in energy density (1.3 kcal/g or 5.3 kJ/g) and a good source of digestible protein (average of 7.7 g of protein/0.5 c). Pulse carbohydrates are slowly digested (see below), which allows some of the lowest GI among carbohydrate-containing foods. Pulse GI typically range from ~29 to 48 (using glucose as the standard) compared with GI of 32–36 for dairy, 39–64 for fruit, 42–72 for grains, 49–80 for breakfast cereals, and 49–97 for root vegetables (15–17). The relatively slow digestibility and hence low GI of pulses has been attributed to several constituents, including carbohydrate composition, protein content and protein-starch matrix, and anti-nutrient factors such as enzyme inhibitors (e.g. amylase inhibitor, trypsin inhibitor), phytates, lectins, saponins, and tannins (18,19). The following section provides a brief description of several of these constituents. The roles of fiber, energy density, carbohydrate type, GI and glycemic load, and protein in energy regulation and weight control in general have been reviewed in detail elsewhere (20–29).

**Pulse carbohydrates**

Starches account for 22–45% of pulse grain weight depending on the source, whereas starch content is low in the oilseeds (30). As is typical of other grains, pulse starches are composed of amylose, a linear α-1,4-linked glucan with few branches in the molecular weight range of $10^5–10^6$, and amylopectin, a highly branched and much larger molecule (molecular weight $10^7–10^9$) composed of α-1,4-linked glycosyl units of varying lengths connected by α-1,6 branch points. Architecturally, amylopectin is divided into clusters containing the exterior branches and short linear chains, and an internal region containing longer linear chains linking clusters. Both the amylose long linear chain and the amylopectin external linear chains reassociate or "retrograde" on cooling following gelatinization, although this retrogradation occurs much faster in amylose. Pulse starches generally have a higher content of amylose compared with cereal and tuber starches; this factor plus their associated high capacity for retrogradation may reduce the starch digestion rate, rendering them either slowly digestible and/or resistant to digestion.

**Slowly digestible starch and resistant starch.** A number of reports infer a slowly digestible or resistant character of the starch in pulses (31–34). Slowly digestible starch is a term given to that fraction of starch that is not rapidly digested but digests and absorbs slowly throughout the course of the small intestines. The term resistant starch applies to the fraction that is not digested by the human α-glucosidases, reaching the colon undigested with a general fate to be fermented by saccharolytic bacteria. These 2 nutritional classes of starch are perhaps best measured in vitro as described by Englyst et al. (35) as starch digested by their system between 20 and 120 min and that undigested at 120 min, respectively.

The basis for the moderated digestion rate of pulse starches remains rather unclear. Reports generally implicate cellular and cotyledon tissue structures in impeding enzyme access to the starch or their comparably high amylose content, as discussed above (34,36,37). Certainly, processing the grains to disrupt native macrostructures increases the rate and extent of starch digestion, thus supporting the idea that slow digestion is at least partly related to digestive enzymes’ poor access to starch (38,39).

**Dietary fiber.** A recent thorough review of dietary fiber in pulses can be found in Tosh and Yada (40). In their raw state, pulses are high in fiber, with ~15–32% total dietary fiber; of this, approximately one-third to three-quarters is insoluble fiber and the remaining is soluble fiber. Insoluble fiber is associated with fecal bulking through its water-holding capacity, whereas soluble fiber ferments, positively affecting colon health through production of SCFA, lowered pH, and potential microbiota changes. Viscous soluble fiber may also increase gastric distention and help to slow gastric emptying rate (20).

**Oligosaccharides.** The oligosaccharides of pulses are often considered a negative attribute due to their high fermentability, with their associated rapid gas production and discomfort. Technically known as α-galactosides, they are derived from sucrose and have 1–3 α-1,6-linked galactosyl units attached. They are commonly known as raffinose (1 galactosyl unit), stachyose (2 galactosyl units), and verbascose (3 galactosyl units). Although generally considered a problem, and methods have been developed to partially remove them, the oligosaccharides may also be considered prebiotics (34), which are thought to be beneficial for health. α-Galactosidase, found in the product Beano, can be used to digest the galactosyl units from these oligosaccharides, leaving sucrose for further digestion.

**Pulse proteins**

The 2010 review by Boye et al. (41) provides comprehensive information on protein ranges in pulses, types of pulse proteins, their functional properties, and the effects of processing. Briefly, the amount of protein in pulses is ~17–35% on a dry weight basis. In terms of solubility in specific solvents, pulse proteins fall primarily into the albumin (water-soluble) and globulin (salt-soluble) classes. The storage proteins legumin and vicillin are globulins, and the albumins comprise the heterogeneous group of enzymes, amylase inhibitors, and lectins. In general, macronutrient studies have shown that protein is more satiating than carbohydrates or lipids (42,43). Moreover, the protein in pulses (44) and soybeans (7) has been implicated in providing satiety; however, little is known regarding whether it is a specific property or more than 1 property of these proteins that elicit this effect or simply the inherent high amounts. Sufian et al. (45) found that pepsin-derived peptides from “country” beans (Dolichos lablab) stimulated secretion of cholecystokinin, a gut hormone related to satiety. Thus, pulse proteins as consumed may contain bioactive components that contribute to satiety.

**Protease and amylase inhibitors.** Protein-based protease inhibitors found in pulses act on either or both of the serine proteases trypsin and chymotrypsin (46). They are found in comparably high amounts in the pulses compared with other plant foods and
TABLE 1. Selected nutrients per 1/2 c (120 mL) serving of some pulses

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Cowpea (Blackeye)</th>
<th>Lima bean, all types</th>
<th>Black bean</th>
<th>Great Northern</th>
<th>Kidney bean, all types</th>
<th>Pinto bean</th>
<th>Navy bean</th>
<th>Lentil</th>
<th>Split Peas, average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight, g</td>
<td>86</td>
<td>89</td>
<td>91</td>
<td>86</td>
<td>89</td>
<td>99</td>
<td>91</td>
<td>86</td>
<td>82</td>
</tr>
<tr>
<td>Energy, kcal</td>
<td>115</td>
<td>104</td>
<td>108</td>
<td>114</td>
<td>104</td>
<td>112</td>
<td>108</td>
<td>115</td>
<td>115</td>
</tr>
<tr>
<td>Protein, g</td>
<td>7.6</td>
<td>7.3</td>
<td>7.5</td>
<td>7.6</td>
<td>7.3</td>
<td>7.3</td>
<td>7.5</td>
<td>7.7</td>
<td>7.7</td>
</tr>
<tr>
<td>Fat, g</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Carbohydrate, g</td>
<td>20.4</td>
<td>17.9</td>
<td>18.7</td>
<td>20.4</td>
<td>17.9</td>
<td>18.7</td>
<td>18.7</td>
<td>19.6</td>
<td>19.6</td>
</tr>
<tr>
<td>Dietary fiber, g</td>
<td>7.5</td>
<td>7.5</td>
<td>7.5</td>
<td>7.5</td>
<td>7.5</td>
<td>8.1</td>
<td>7.7</td>
<td>8.1</td>
<td>8.1</td>
</tr>
<tr>
<td>Energy density, kcal/g</td>
<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
</tr>
<tr>
<td>% energy carbohydrates</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
</tr>
<tr>
<td>% energy protein</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>% energy fat</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

1 Values are from USDA Standard Reference 22 and are based on edible portions of mature seeds, cooked, boiled, without salt.
2 1 kcal = 4.184 kJ.
3 Values do not add to 100%, because carbohydrate is determined by difference and the assumed Atwater factors of 4, 9, and 4 kcal/g for protein, fat, and carbohydrate, respectively, may not always apply to individual foods.

Pulse phytochemicals

Phenolic compounds. Pulses contain a range of phenolic compounds, with the darker grains such as black beans and red kidney beans generally having higher amounts. The phenolic compounds in pulses are generally polyphenols and include tannins, phenolic acids, and flavonoids (46). Antioxidant activity is related to total phenolic content (48). Their potential role in weight management is unclear, although studies indicate that certain phenolics interfere with enterocyte glucose absorption through interference with the glucose transporters (49,50).

Phytates. Phytic acid, also known as myo-inositol hexaphosphate, is the major storage form of phosphate in plant cells (51). Pulses are one of the primary sources of phytate in the diet, the others being cereals, oilseeds, and nuts. Phytate has been shown to reduce the in vitro rate of starch digestion and delay postprandial glucose absorption in humans (52), which could contribute to satiety and delay the return of hunger, as discussed below.

Pulse consumption and energy regulation

It is unknown which of the pulse components described above has the strongest influence on appetite regulation and potentially energy balance or whether multiple factors work in consort. Nonetheless, several lines of evidence exist that suggest that pulse consumption could potentially increase satiety and help with weight control when consumed regularly. These studies are reviewed below.

Pulse consumption, glycemic response, and satiety

Most studies (15,31,53–60), although not all (61,62), consistently show lower glucose and insulin responses to consumption of controlled amounts of pulses compared with other foods. The glycemic response (peak and area under the curve) to pulses is at least 45% lower than that of other carbohydrate-containing foods such as cereals, grains, pasta, biscuits, and tuberous vegetables (31). Whether a low glycemic response per se is mechanistically related to a reduction in satiety is a topic of much debate (63–66), although there are some data to support a slower return of hunger in response to low-GI meals in general (67–69).

Additionally, a second meal effect has been observed whereby a reduced glycemic response to a second meal occurs after consumption of a first meal low in GI (70,71). In those studies, a first meal containing barley and lentils improved glucose tolerance to a second meal compared with a first meal containing whole-meal bread. The second meal effect is thought to be due primarily to an increase in colonic fermentation and only minimally to a reduction in gastric emptying rate (72,73). Fermentation in the colon produces SCFA, which can be oxidized and used for energy (74) in preference to glucose. SCFA may also suppress hepatic glucose production (75). Both of these mechanisms could lead to more stable glucose patterns over time, which some have hypothesized may result in reduced appetite and energy intake (76,77). Furthermore, an increase negatively affect digestibility of food proteins if not processed (i.e., mainly cooked) properly (41). They do not appear to have an important role in weight management. On the other hand, α-amylase inhibitors found in pulses, specifically dry beans (up to 2–4 g/kg), reduce starch digestibility and thus energy availability (46). Isolated α-amylase inhibitor lowers postprandial glycemic responses (47), although it may be inactivated through cooking or other processing methods (47). As discussed later in this review, several pulse extracts prepared with processing methods thought to retain amylase inhibitor activity have been tested in randomized, placebo-controlled trials for their potential to affect weight and fat loss.
the low-unavailable carbohydrate lunch and dinner, but not breakfast. Hunger was significantly greater and fullness significantly less after the low-unavailable carbohydrate lunch and dinner, but not breakfast, compared with the respective high-unavailable carbohydrate meals. The diet high in unavailable carbohydrates also resulted in a significantly lower rapid rise in postprandial carbohydrate oxidation, and the difference in carbohydrate oxidation between diets was inversely correlated with hunger ratings. The investigators concluded that delayed carbohydrate oxidation associated with the diet high in unavailable carbohydrate resulted in less hunger. Because it is impossible to determine whether the different responses to the 2 diets were attributable to the difference in pulse content per se, it is recommended that more studies designed to better isolate the effects of pulses and incorporating the scope of measurements included in this study be conducted.

Wong et al. (60) conducted a series of 3 preload experiments to study the effects of processing, recipe, and pulse variety on glycemic and appetitive responses and energy intake of pizza meals 2 h later. In the first 2 experiments, preload meals were matched for carbohydrate amount (50 g) and in the 3rd, they were matched for energy. In the first experiment, 2 types of canned navy beans (plain) were compared with navy beans that were soaked as one would prepare at home and made into a baked bean recipe. A glucose drink served as the control. The glycemic responses to the bean meals were not significantly different, and, not unexpectedly, all were significantly lower than the glucose drink. Appetite response was significantly lower only for the homemade beans compared with glucose, and the amount of pizza consumed in a test meal 2 h later was lower after the 2 canned beans but not the homemade beans. In the second experiment, 3 different recipes made with canned navy beans (tomato sauce, maple style, pork, and molasses) and one made with homemade navy beans (pork and molasses) were compared with white bread as the control. Only 1 of the canned recipes (tomato sauce) and the homemade recipe led to a glycemic response that was significantly lower than that of white bread. The appetite responses tended to be lower for these same recipes, but these differences did not reach significance ($P = 0.09$) and pizza intake did not differ among treatments.

Table 2. Summary of pulse nutritional and antinutritional components that may help with weight management

<table>
<thead>
<tr>
<th>Component</th>
<th>Brief description of mechanism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrate</td>
<td>Slowly digestible, low glycemic, low GI (glycemic index)</td>
</tr>
<tr>
<td>Dietary fiber</td>
<td>Soluble, viscous fiber gels in small intestine, slowing gastric emptying and hence absorbance (ileal brake). Fermentable fiber is digested in the colon by bacteria, which liberates SCFA that may be used for energy, thereby sparing protein and glucose. SCFA may also suppress hepatic glucose production. The SCFA propionate may also stimulate satiety.</td>
</tr>
<tr>
<td>Starch make-up</td>
<td>High amylose:amylopectin ratio compared with other vegetables and root crops. Amylose also ferments in the colon and therefore may have effects similar to fiber.</td>
</tr>
<tr>
<td>Resistant starch</td>
<td>Amylose starch and the external branches amylopectin starch gelatinize as a result of heating, thereby becoming resistant to digestion. α-Glucosidase enzymes are less apt to reach the areas needed to digest the starch. The starch-protein matrix may also reduce starch digestion rate by limiting enzyme accessibility to the starch.</td>
</tr>
<tr>
<td>Oligosaccharides</td>
<td>Considered prebiotic, therefore may facilitate the growth of bacteria in the large intestine, which may help to spare protein and glucose use for energy and stimulate satiety and the liberation of SCFA as described above.</td>
</tr>
<tr>
<td>Protein</td>
<td>About 25% energy from protein; bound to starch in matrix, limiting the accessibility of both to digestive enzymes; limiting in amino acids lysine and methionine but when coupled with complementary protein sources such as corn or grain (higher in these 2 amino acids) becomes a complete protein source. Dietary protein may stimulate gut hormones to increase satiety, increase the energy cost of digesting and absorbing a meal high in protein, and spare fat-free mass during energy restriction.</td>
</tr>
<tr>
<td>Digestive enzyme inhibitors</td>
<td>Protease inhibitors may inhibit enzymes needed for protein digestion (e.g. trypsin and chymotrypsin); however, they are mostly destroyed by cooking and are not thought to play an important role in weight regulation. Amylase inhibitors may inhibit pancreatic amylase, reducing carbohydrate digestion, but these are also thought to be mostly destroyed during cooking and processing of whole pulses. However, extracts from Phaseolus vulgaris may be heat treated and prepared in such a way as to preserve the amylase inhibitor activity.</td>
</tr>
<tr>
<td>Phytochemicals</td>
<td>Phenolic compounds may reduce enterocyte glucose absorption by interfering with glucose transporters that may help delay postprandial glucose absorption, which may contribute to satiety and delay the return of hunger. Phytic acid (myo-inositol hexaphosphate), the major storage form of phosphate in plant cells, may help delay postprandial glucose absorption, which could contribute to satiety and delay the return of hunger.</td>
</tr>
<tr>
<td>Energy density</td>
<td>Moderate energy density may contribute to satiety, helping to limit energy intake.</td>
</tr>
</tbody>
</table>

in satiety has been linked with the consumption of bread prepared with the SCFA propionate (78). Colonic fermentation and its effects may be long-lasting, as it has been observed to occur up to 13 h after the previous meal (73).

Few studies have specifically measured the satiety and appetite responses to pulse consumption (Table 3). In 2 different experiments, Leathwood and Pollet (56) fed participants hachis parmentier (the French version of shepherd’s pie) made with either potato purée or bean purée. Glycemic responses to the bean meals were significantly lower than with the potato meals. In addition, participants reported significantly less hunger at 180 min, greater satiety at 240 min, and a lower desire to consume “something tasty” after consuming the bean meals. In this study, the meals were not matched for carbohydrate content, with the bean meals containing 7.5 g less carbohydrate than the potato meals. In another study, Holt et al. (79) measured satiety responses over 2 h to 38 foods. All foods were served in 240-kcal portions (1 MJ). Of the protein-rich foods, ling fish led to greater satiety compared with lentils and baked beans. Also, baked beans and eggs led to greater satiety than did white bread.

Sparti et al. (57) fed 14 healthy, normal-weight participants 3 meals that were either high or low in unavailable carbohydrate and measured metabolic and appetitive responses to the meals over 24 h in a metabolic chamber. The lunch and dinner meals from the high-unavailable carbohydrate regimen contained pulses (chickpea salad at lunch and red bean salad at dinner). The diets were controlled for energy and macronutrient distribution but differed in fiber (60 vs. 3 g), slowly and rapidly digestible starch (63 vs. 24 g of slowly digestible starch), and resistant starch (18 vs. 4 g). Hunger was significantly greater and fullness significantly less after the low-unavailable carbohydrate lunch and dinner, but not breakfast, compared with the respective high-unavailable carbohydrate meals. The diet high in unavailable carbohydrates also resulted in significantly lower postprandial carbohydrate oxidation and a lower decrease in postprandial glucose absorption, which could contribute to satiety and delay the return of hunger. The investigators concluded that delayed carbohydrate oxidation associated with the diet high in unavailable carbohydrate resulted in less hunger. Because it is impossible to determine whether the different responses to the 2 diets were attributable to the difference in pulse content per se, it is recommended that more studies designed to better isolate the effects of pulses and incorporating the scope of measurements included in this study be conducted.
<table>
<thead>
<tr>
<th>Reference</th>
<th>n</th>
<th>BMI, kg/m²</th>
<th>Meals</th>
<th>Meals matched for</th>
<th>Measurement duration, h</th>
<th>Satiety effect?</th>
<th>Subsequent ad libitum energy intake effect?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leathwood and Pollet (56), study 1</td>
<td>6</td>
<td>145–30.4</td>
<td>Hachis parmentier (shepherd’s Pie) topped with either bean puree or potato puree</td>
<td>Energy</td>
<td>4</td>
<td>Bean &lt; potato ($P &lt; 0.10$ for hunger at min 180)²</td>
<td>Not measured</td>
</tr>
<tr>
<td>Leathwood and Pollet (56), study 2</td>
<td>6</td>
<td>192–27.2</td>
<td>Hachis parmentier (shepherd’s Pie) topped with either bean puree or potato puree</td>
<td>Energy</td>
<td>4</td>
<td>Bean &gt; potato (stomach fullness at min 240); Bean &lt; potato (hunger and desire to eat “something tasty” at mins 180 and 240)²</td>
<td>Not measured</td>
</tr>
<tr>
<td>Holt et al. (79)</td>
<td>11</td>
<td>24.3 ± 3.1 (SD)</td>
<td>Canned lentils, canned baked beans, other foods</td>
<td>Energy</td>
<td>2</td>
<td>Fish &gt; lentils and baked beans; baked beans = eggs &gt; white bread</td>
<td>Not measured</td>
</tr>
<tr>
<td>Sparti et al. (57)</td>
<td>14</td>
<td>19–25</td>
<td>High- vs. low-unavailable carbohydrate breakfast, lunch, and dinner; included pulses in lunch and dinner</td>
<td>Energy, macronutrients</td>
<td>24</td>
<td>High unavailable &gt; low unavailable at lunch and dinner</td>
<td>Not measured</td>
</tr>
<tr>
<td>Johnson et al. (62)</td>
<td>11</td>
<td>247 ± 0.8 (SEM)</td>
<td>Bread made with conventionally processed chickpea flour vs. extruded chickpea flour (more subject to retrogradation)</td>
<td>Available carbohydrate, fat</td>
<td>2</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Pai et al. (44)</td>
<td>32</td>
<td>16–31</td>
<td>Traditional Indian (Asian) breakfasts: Rice-pulse vs. rice based vs. wheat based</td>
<td>Energy</td>
<td>2</td>
<td>Rice-pulse &gt; all others</td>
<td>Not measured</td>
</tr>
<tr>
<td>Wong et al. (60), study 1</td>
<td>14</td>
<td>20–25</td>
<td>Canned beans, homemade beans vs. glucose</td>
<td>Available carbohydrate</td>
<td>2</td>
<td>Homemade beans &gt; glucose</td>
<td>(Pizza meal) Canned &lt; homemade and glucose</td>
</tr>
<tr>
<td>Wong et al. (60), study 2</td>
<td>14</td>
<td>20–25</td>
<td>Canned: maple, pork, and molasses, or tomato sauce vs. homemade: pork and molasses vs white bread</td>
<td>Available carbohydrate</td>
<td>2</td>
<td>Homemade &gt; white bread ($P = 0.09$)</td>
<td>(Pizza meal) N = no</td>
</tr>
<tr>
<td>Wong et al. (60), study 3</td>
<td>15</td>
<td>20–25</td>
<td>Pulse variety: chickpeas, lentils, navy beans, yellow peas vs. white bread vs. water</td>
<td>Energy</td>
<td>2</td>
<td>All pulse varieties = white bread &gt; water</td>
<td>(Pizza meal) All varieties = white bread; chickpeas = water</td>
</tr>
</tbody>
</table>

1 All studies were performed in healthy adults (no chronic disease) ≤ 45 y of age.
² Comparisons were planned a priori only for min 180 and 240.
Finally, in the 3rd experiment, which compared responses to different pulse varieties (chickpeas, lentils, navy beans, yellow peas), water and white bread, glycemic responses varied somewhat and tended to be lowest for lentils and chickpeas, but differences in appetite or subsequent pizza intake were not observed. This study provided only weak evidence and mixed findings for a satiety-promoting effect of pulses depending on how they are processed and prepared. Additional studies are needed comparing different recipes and processing methods of pulses to meals with alternative protein sources such as meat.

Glycemic and insulinemic responses and energy intake subsequent to consumption of breads made with normally processed chickpea flour, extruded chickpea flour, or white wheat flour were measured (62). The extrusion process involves higher temperatures and shear compared with those used during normal processing. Gelatinized starch during extrusion processing may fragment and align differently than when normally processed and, by retrogradation, potentially increase the resistant starch content of the chickpea flour. The results showed a significantly higher insulin response and a nonsignificant tendency toward a lower glyceremic response after ingestion of the chickpea bread (normal process). However, neither satiety nor energy intake differed among bread type at a buffet meal 2 h later, perhaps due to the variation in food form (chickpea flour) compared with other studies that have used whole pulses. In addition, the starch and fiber contents of the breads were not matched, which could have affected the results. Further studies on foods made with pulse flours may be of interest, given its potential as a functional ingredient (59) and the expanding variety of products made with pulse flours now available, such as tortillas, pasta, and bakery products.

Even fewer studies have measured satiety responses to pulse consumption in studies lasting longer than 1 d. McCrory et al. (80) recently completed a randomized intervention comparing 3 doses of pulse consumption on weight loss and adherence to 30% reduction in baseline energy intake over 6 wk. The doses were 1 Tbsp/d (15 mL), 0.5 c/d (120 mL), or 1.8–2.5 c/d (432–600 mL) for 6 d/wk. There was a significant time-pulse dose group interaction effect on average daily satiety ratings, where satiety ratings were highest in the group receiving 0.5 c/d, particularly over the first 3 wk. In another recent study using a nonrandomized design in which participants served as their own controls (81), individuals were followed for a period of 4 wk on their usual diet, followed by 12 wk of chickpea supplementation (mean 104 g/d, which is just over 0.5 c/d), then another 4 wk on their usual diet. Participants reported a significant increase in feelings of satiation in the chickpea phase relative to the first habitual phase and a significant decrease in satiation in the second habitual phase relative to the chickpea phase. However, it is unclear when these ratings were collected during the study (i.e., daily, weekly, or at the end of each phase).

In summary, short-term studies (mostly single-meal studies) indicate reduced hunger and increased satiety 2–4 h after pulse consumption when meals were controlled for energy but not when controlled for available carbohydrate. This suggests that at least part of the effect of pulses on satiety may be mediated by available carbohydrate amount or composition. Across all of these studies, the control or comparison foods varied widely, from potato to cereal grains to glucose and white bread. This raises the question of the optimal control food to use in determining whether pulse consumption helps to increase satiety in real-world situations. One possibility is to include a food that might otherwise be consumed in normal daily life instead of pulses, such as another protein source like meat, poultry, or fish, or an alternative carbohydrate source, such as whole grains. The effects of pulse consumption on subsequent energy intake are still largely uncertain, because very few of these studies measured subsequent energy intake. In addition, more studies are needed to identify whether regular daily pulse consumption can help to increase satiety on a regular basis relative to other foods and potentially help with weight control in the longer term.

**Pulse consumption and body weight**

**Observational studies.** One way to determine whether longer term pulse consumption may affect body weight is to determine whether an association exists between pulse consumption and body weight cross-sectionally. Very few studies have examined this relationship. Papanikolaou and Fulgoni (82) reported on the association of consumption of beans (a subgroup of pulses, as described above) with dietary quality and obesity risk in >8000 adult participants in the NHANES 1999–2002 using data from a single, multiple pass, 24-h dietary recall. They found that individuals who had consumed variety beans or baked beans had significantly lower body weights compared with those who had not consumed beans. In addition, the odds of being obese (BMI ≥ 30 kg/m²) was significantly lower in variety bean consumers and baked bean consumers compared with nonconsumers (odds ratio = 0.78 and 0.77, respectively). Interestingly, when variety bean consumers were analyzed separately from baked bean consumers, the reduced risk of overweight or obesity was no longer observed in the baked bean consumers compared with nonconsumers. There were several dietary differences associated with bean intake that could have mediated these relationships. Compared with bean nonconsumers, both baked bean consumers and variety bean consumers had significantly higher intakes of total legumes, fiber, and minerals and lower intakes of discretionary fat (trend toward significance in variety bean consumers). The variety bean consumers had lower intakes of meat and added sugars, whereas the baked bean consumers had lower intakes of total grains, whole grains, and vegetables and higher intakes of added sugars. These dietary confounders were not controlled for in analyses, so it is difficult to determine the degree to which the relative leanness in variety bean and baked bean consumers may be attributed specifically to bean consumption. Minimally, this study showed that bean consumption is associated with an overall dietary pattern and lifestyle that tends to be associated with relative leanness. This suggestion is also supported by other studies described below.

A few studies examined relationships between dietary patterns incorporating pulses but did not specifically isolate pulse consumption associations in their analyses. Most (83–88), although not all (89,90), showed an inverse association of the dietary pattern incorporating pulses with BMI or BMI increase over time. Other types of studies examined overall dietary patterns of high fruit and vegetable intake or a vegetarian lifestyle typically incorporating large amounts of pulses. However, pulse intake was not quantified in those studies. As reviewed (91), most studies show that vegetarians weigh less than nonvegetarians. In addition, vegans and those on macrobiotic diets generally weigh less than lacto-ovo vegetarians. Others reviewing studies on fruit and vegetable consumption (92,93) note that despite methodological inconsistencies among different studies leading to somewhat mixed findings, a pattern of higher fruit and vegetable intake has generally been associated with lower body weight.

In summary, studies examining the potential associations between pulse consumption and weight status consistently show that individuals with lower BMI consume a greater amount of pulses as part of their usual diet. However, very few studies have been conducted and only 1 considers beans separately from other
pulses or legumes or from other food groups. Finally, these studies should be interpreted with caution, because confounding may exist, as is usually the case with cross-sectional associations. Cause and effect cannot be assumed, because pulse consumption may be part of an overall lifestyle that confers maintenance of healthy weight. Experimental study designs are necessary to determine whether pulses can be implicated as having independent effects on body weight.

**Experimental studies in humans**

**Pulse consumption and weight loss during intentional energy restriction.** Very few interventions testing effectiveness of whole pulses for weight loss during intentional caloric restriction have been published (Table 4). The earliest study was conducted in 1987 (94) in 15 type 2 diabetics with a mean BMI of 24.8 kg/m²; about one-half of the participants were normal weight (BMI > 25 kg/m²) and one-half were overweight or obese (BMI ≥ 25 kg/m²). A 3-wk crossover design was used. Seven participants began with the control diet and 8 began with a legume-based diet. It is not stated whether the order of the diets was randomized; however, each participant switched to the other diet after 3 wk and there was no wash-out period. Diets were designed to provide ~1600 kcal/d (6.7 MJ/d). Because of the wide BMI range in this study, a 1600-kcal/d intake would likely be anywhere from a 15–40% energy deficit, depending on initial energy requirement (95). Both diets were 20/34/56% of energy from protein/carbohydrate/fat, and the legume-based diet contained ~21% of energy from legumes. Based on 115 kcal (481 kJ) per 0.5 cup of pulses (Table 1), the legume dose was probably about 1.5 c/d (21% of 1600 kcal = 336 kcal/d or 1.4 MJ/d of legumes). The legume-based diet contained mostly pulses (green peas, brown beans, white beans, chickpeas, lentils, and yellow peas), but there was also a small amount of soybeans and green beans included. After 3 wk of consuming each diet, there was a small but significant weight loss after consuming the control diet but not the legume-based diet (no values given). Compliance monitoring was not mentioned in the publication.

The study by Sichieri et al. (96) was originally published in Portuguese but was summarized in English in a subsequent paper (85). They conducted a randomized controlled trial in which 40 overweight or obese women (BMI ≥ 27 kg/m²) were provided with an 1800-kcal/d (7.5 MJ/d) diet incorporating either rice and beans twice a day (with no meat) or lean meat twice a day. Diets had protein/carbohydrate/fat distributions of 14/15/71% of energy (beans and rice) or 18/25/57% of energy (lean meat). The rice and beans diet resulted in greater weight loss after 1 mo (2.4 vs. 0.9 kg; P = 0.04); however, the difference was not significant after 2 mo (3.8 vs. 1.5 kg; P = 0.10). The lack of a difference at 2 mo was likely due to loss of follow-up, which was 35% in the rice and beans group and 45% in the lean meat group. Potential reasons for the high drop-out rate were not discussed. However, the results of that study strongly suggest that pulses could aid weight loss during intentional caloric restriction if drop-out could be prevented or substantially reduced.

In the 6-wk intervention trial by McCrory et al. (80) described above, 49 overweight and obese participants (BMI 25–35 kg/m²) were randomized to consume either 1 Tbsp/d (low), 0.5 c/d/ (medium), or 1.8–2.5 c/d (high) of pulses for 6 d/wk while reducing their energy intake by 30% of baseline energy requirements daily. Foods with the requisite amount of pulses were provided as 4 servings/d [250 kcal (1.0 MJ) and 300 kcal (1.3 MJ)] for women and men, respectively. The foods were familiar foods such as casseroles and pasta dishes, and a variety of pulses were used including (but not limited to) chickpeas, lentils, black beans, pinto beans, navy beans, and split peas. Thus, 1000 (4.2 MJ/d) kcal/d were provided to women and 1200 kcal/d (5.0 MJ/d) were provided to men. Participants were counseled about how to choose the remainder of their energy intake (to meet the target intake) by following an exchange list. In addition to weight loss, adherence to the energy intake target was an outcome of interest. Seven participants dropped out of the study (2 from each group and 1 prior to randomization). Interestingly, the results showed there was no dose-response effect of pulse consumption on weight loss, with the weight loss being 1.8 ± 1.9 kg, 3.9 ± 2.2 kg, and 2.3 ± 2.3 kg in the low-, medium-, and high-pulse groups, respectively, and differing significantly only between the low- and medium-pulse groups. Energy intake from the multiple pass 24-h recall dietary intake assessments also reflected a higher energy intake in the high-pulse group. The reasons for the lack of a greater weight loss in the high-pulse group are several and could be due to a “halo” effect (97,98) of the high pulse provision on energy intake, an adaptation to the high pulse intake that disrupted appetite regulation mechanisms (99) or lack of compliance with the high pulse intake. However, “flatulence and intestinal gas” ratings assessed by a 9-point rating scale were highest in the high-pulse group, suggesting that the group as a whole compliant with their intake of provided pulses.

In an 8-wk trial (100), 35 overweight or obese men were randomized to consume a control diet, a legume diet, a fatty fish diet, or a high-protein diet. The control, legume, and fatty fish diets were designed to provide 17/30/53% of energy as protein/carbohydrate/fat, whereas the high-protein diet was designed to provide 30/30/40% of energy from protein/carbohydrate/fat. Protein sources in the high-protein diet were primarily meat, eggs, and lean dairy products. For the legume diet, neither legume dose nor type was mentioned, but legumes were required 4 d/wk, fish was not allowed, and other animal protein intake was decreased. All diets were designed to produce a 30% energy deficit. Compliance was monitored weekly by interview with a dietitian and 3-d weighed food intake records at the week prior to the intervention and at wk 7. Based on reported intakes, compliance with the prescribed diets appeared to be quite good. Results showed significant weight loss in all 4 groups, but the legume group (–8.3% of initial weight) and high-protein group (–8.4% of initial weight) lost significantly more than the control group (–5.5% of initial weight). Absolute changes in body weight were not reported.

In the most recently published trial (101), 30 overweight and obese participants consumed a reduced energy intake diet for 8-wk prescribed at 30% energy restriction based on initial energy requirements. Participants were randomized to a treatment group that consumed 4 servings/wk of pulses or to a control group that restricted pulses during this time period. One serving was defined as 160–235 g of cooked pulses, depending on the prescribed energy intake. Because pulses average 90 g/0.5 c (120 mL) (Table 1), 1 serving in this study ranged from ~0.9 to 1.3 c (216-312 mL). Therefore, the total dose ranged from 3.6 to 5.2 c (756-1092 mL) of pulses/wk. The prescribed macronutrient distribution was the same for both groups, which was a protein/carbohydrate/fat distribution of 17/53/30 percent of energy. Compliance with the assigned pulse consumption and macronutrient distribution was good, as indicated by weekly monitoring by a dietitian and by 3-d weighed food records during the week prior to the intervention and during wk 7. Results showed significantly greater decreases in BMI and body weight expressed as percent of initial value in the pulse-consuming group compared with the control group (–2.0 vs. –0.9 kg/m² and –7.8 vs. –5.3%, respectively). Percentage body fat and waist circumference decreases, however, did not
<table>
<thead>
<tr>
<th>Reference</th>
<th>Design</th>
<th>BMI, kg/m²</th>
<th>Pulse dosage and/or types</th>
<th>Other intervention components</th>
<th>Δ Weight, kg</th>
<th>Significant difference between groups?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Karlstrom et al. (94)</td>
<td>3-wk crossover design, unclear if order randomized (n = 15 type 2 diabetics with inadequate control)</td>
<td>19–33</td>
<td>1.4 c/d legumes (mostly green peas, brown beans, white beans, chickpeas, lentils, yellow peas, but also soybeans and green beans)</td>
<td>Provided 1600 kcal/d²; both diets were 20/56/34% energy from P/C/F; fiber 23.7 vs. 36.7 g/d for control and legume diet, respectively</td>
<td>Legume: −0.4 kg control: −0.7 kg (SD not provided)</td>
<td>Yes (legume &lt; control)</td>
</tr>
<tr>
<td>Sicheiri et al. (96)</td>
<td>8 wk RCT (n = 40 women)</td>
<td>≥27</td>
<td>Rice and beans vs. lean meat twice a day (dose unclear)</td>
<td>Provided 1800 kcal/d²; P/C/F was 14/71/15% energy (rice and bean), 18/57/25 (lean meat)</td>
<td>4 wk, rice/bean: −24 kg lean meat: −09 kg (SD not provided) 8 wk, rice/bean: −38 ± 1.8 kg lean meat: −15 ± 0.9 kg</td>
<td>Yes at 4 wk, no at 8 wk (35% drop-out at 8 wk)</td>
</tr>
<tr>
<td>McCrory et al. (80)</td>
<td>6 wk RCT (n = 42 men and women)</td>
<td>25–35</td>
<td>3 Treatments: all 6 d/wk high pulse 18 c/d women, 2.5 c/d men; medium pulse 0.5 c/d; low pulse (control): 1 T/d</td>
<td>Prescribed 30% energy deficit; pulses provided</td>
<td>High pulse: −23 ± 2.3 kg medium pulse: −39 ± 2.2 kg low pulse: −1.8 ± 1.9 kg</td>
<td>Yes, medium vs. low</td>
</tr>
<tr>
<td>Abete et al. (100)</td>
<td>8 wk RCT (n = 35 men)</td>
<td>31.8 ± 3</td>
<td>4 Treatments: legume 4 d/wk and avoid fish vs. fatty fish 3 d/wk and avoid legumes vs. high protein (meat, eggs, and lean dairy) vs. control (avoid legumes and fatty fish)</td>
<td>Prescribed 30% energy deficit; P/C/F was 17/40/30% energy for legume, fatty fish and control, and 30/40/30% energy for high protein; fiber was 26.5 g/d in legume diet vs 181–203 g/d in the other diets</td>
<td>Legume: −8.3 ± 2.9% fatty fish: −64 ± 2.6% high protein: −8.4 ± 12% control: −55 ± 2.5% of initial weight</td>
<td>Yes (legume = high protein &gt; control)</td>
</tr>
<tr>
<td>Hermsdorff et al. (101)</td>
<td>8 wk RCT (n = 30 men and women)</td>
<td>325 ± 4.5</td>
<td>Pulse: 4 serving/wk = 3.6–5.2 c/wk vs. control: limit pulse intake</td>
<td>Prescribed 30% energy deficit; 17/53/30% energy from P/C/F for both diets; fiber was 260 vs. 18.0 g/d for pulse vs control diet</td>
<td>Pulse: −7.8 ± 2.9% control: −53 ± 2.7% of initial weight</td>
<td>Yes</td>
</tr>
</tbody>
</table>

1 RCT, randomized controlled trial; P, protein; C, carbohydrate; F, fat.
2 1 kcal = 4.184 kJ.
<table>
<thead>
<tr>
<th>Reference</th>
<th>Product Description</th>
<th>Design</th>
<th>BMI, kg/m²</th>
<th>Dosage</th>
<th>Other intervention components</th>
<th>Δ Weight, kg</th>
<th>Significant difference between groups?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thom (124)</td>
<td>Phaseolamin (white bean extract, 200 mg; inulin, 200 mg; Garcinia cambogia, 50 mg)</td>
<td>12-wk RCT, double-blind</td>
<td>Overweight + obese</td>
<td>2 tablets immediately after each meal (breakfast, lunch, and dinner)</td>
<td>Prescribed 1200 kcal/d&lt;sup&gt;2&lt;/sup&gt; low-fat diet</td>
<td>Active: −3.5 ± 2.0</td>
<td>Yes (34 completed; intent to treat analysis)</td>
</tr>
<tr>
<td>Udani et al. (125)</td>
<td>Phaseolamin (previously sold as Phaseolamin)</td>
<td>8-wk RCT, double-blind</td>
<td>Obese</td>
<td>1500 mg + 8 fl oz water with lunch and dinner</td>
<td>Prescribed high-fiber, low-fat diet; instructed to eat majority of CHO at lunch and dinner</td>
<td>Active: −1.7, placebo: −0.8</td>
<td>No (intent to treat analysis)</td>
</tr>
<tr>
<td>Koike et al. (126)</td>
<td>Phaseolamin 1600 (white bean extract, 750 mg; clove, 200 mg; lysine, arginine, alanine, 20 mg each)</td>
<td>8-wk open label, no control group</td>
<td>Normal weight + overweight</td>
<td>2 capsules taken 30 min before lunch and dinner with water</td>
<td>Normal meals and exercise routine</td>
<td>Active: −1.8</td>
<td>n/a</td>
</tr>
<tr>
<td>Opala et al. (127)</td>
<td>Nutrin appealed PLUS (Finzelbreh, GmbH &amp; Co. KG) tablet 1: extracts of asparagus, green and black teas, guarana, mate, and kidney bean; tablet 2: extracts of kidney bean pods, Garcinia cambogia, chromium yeast</td>
<td>12-wk RCT, double-blind</td>
<td>Overweight + obese</td>
<td>2 tablets with each main meal (1 before and 1 after each meal)</td>
<td>Prescribed 1500 kcal/d&lt;sup&gt;2&lt;/sup&gt; daily walking</td>
<td>Active: −2.0 ± 2.6</td>
<td>No for kg, yes for g/h exercise, yes for percentage body fat (not shown)</td>
</tr>
<tr>
<td>Celleno et al.</td>
<td>Phase 2 Starch neutralizer (Phaseolamin 2250) with 445 mg Phaseolus vulgaris extract, 0.5 mg chromium picolinate, calcium phosphate, vitamin B-3, and others</td>
<td>30-d RCT, double-blind</td>
<td>5–15 kg overweight, mean BMI: −26.0 ± 2 kg/m²</td>
<td>1 tablet/d before the main meal</td>
<td>Prescribed 2000–2250 kcal/d&lt;sup&gt;2&lt;/sup&gt; carbohydrate rich</td>
<td>Active: −2.9 ± 1.6</td>
<td>Yes</td>
</tr>
<tr>
<td>Udani and Singh</td>
<td>Phase 2 Starch neutralizer (Phaseolamin 2250) supplied by Pharmachem Labs</td>
<td>4-wk RCT, double-blind</td>
<td>Normal weight, overweight, and obese</td>
<td>2 x 500 mg capsules each at beginning of breakfast and lunch</td>
<td>1800 kcal/d, provided breakfast and lunch, prescribed dinner, prescribed exercise 30 min x 4d/wk, behavior groups 1x/wk</td>
<td>Active: −2.7, placebo: −2.1</td>
<td>No overall, yes for highest CHO tertiles (no for 2 lower tertiles)</td>
</tr>
<tr>
<td>Wu et al. (130)</td>
<td>Phase 2 Starch neutralizer</td>
<td>60-d RCT, double-blind</td>
<td>Overweight + obese</td>
<td>2 x 500 mg tablets 1.5 min before each meal (breakfast, lunch, and dinner)</td>
<td>No details provided</td>
<td>Active: −1.9 ± 0.7</td>
<td>Yes</td>
</tr>
</tbody>
</table>

<sup>1</sup> RCT, randomized controlled trial.
<sup>2</sup> 1 kcal = 4.184 kJ.
differ significantly between groups. Group values for reported energy intake or diet composition during the intervention were not reported; therefore, it is uncertain whether the differences in weight loss between groups could be ascribed to differences in energy intake or other metabolic effects of pulses on energy expenditure.

**Pulse consumption and body weight without energy restriction**

The effects of pulse consumption on body weight can also be explored by examining the results of pulse intervention studies in which chronic disease risk factors were the primary outcomes yet body weight was measured. Most of these studies were designed to provide energy in an amount necessary to maintain body weight. Hence, no significant effects of pulse consumption on body weight were observed over 3- to 7-wk periods (102–111). Pulse consumption under less rigorous feeding conditions (e.g. ad libitum dietary intake, except for the provided pulses and control foods, with advice given to maintain usual dietary and exercise habits) over 2–16 wk also did not affect body weight (112–116). Similarly, body weight was not affected when pulses were added to a prescribed low-fat diet (28–32% of energy) (117). The lack of an effect of pulses on body weight under all of these study conditions is consistent with the suggestion that an increase in fruit and vegetable intake is likely to have only very small or modest effects on body weight loss unless advice on reducing energy intake is provided simultaneously (118). This may not be the case, however, if the fruit and vegetable load is very high or if multiple dietary changes are made at once. In support of this idea, and as Berkow and Barnard reviewed (91), controlled interventions that place participants on a vegetarian or vegan diet for several weeks have resulted in weight changes of 2.5–7.2 kg, with maintenance of these changes shown in a few uncontrolled studies.

**Studies using pulse extracts**

A few human clinical trials have examined the effects of pulse “extracts” taken as a dietary supplement on body weight and related parameters. During normal starch digestion, amylases break α-1,4 bonds to allow it to be broken into more easily digested and absorbable units. The main ingredient in these extracts is thought to be α-amylase inhibitor; thus, the extracts are often referred to as starch blockers. Depending on the method of preparation, other components may also be present in the extracts. The effectiveness of pulse extracts were recently reviewed by Preuss (119). Briefly, extract preparations in the early 1980s were crude and not very effective at blocking starch digestion due at least in part to low amylase inhibitor activity (120). However, extract preparations in the later 1980s and beyond showed greater α-amylase inhibitor activity and, hence, effectiveness at blocking starch digestion in short-term human studies (e.g. (121)). Also, initially there was some concern that the extract preparations contained lectins, which may be harmful to health; however, in animal studies, the extracts have been shown to be safe and the current preparation method is thought to result in the destruction of lectins (122,123). As with all dietary supplements, however, the commercially available preparations are not monitored regularly by the FDA for safety or content.

Several human trials testing the effectiveness of these extracts have been conducted in the last several years (124–130). All but 1 (126) used a randomized, double-blind, placebo-controlled design (Table 5) and all included only initially overweight or obese participants. Intervention length ranged from 4 to 12 wk. Extract doses varied from pills to powders mixed in water taken with 1 or 2 carbohydrate-rich meals a day. In all studies, there was greater weight loss in the treatment group compared with the placebo group, but this difference was significant in only 3 studies. Overall, the mean weight loss among the 6 randomized controlled trials was 0.4 ± 0.2 kg/wk (0.5 ± 0.1% of initial weight/wk) in the treatment groups compared with 0.2 ± 0.2 kg/wk (0.2 ± 0.2% of initial weight/wk) in the placebo groups. Variable results among these studies could be due to factors such as differences in dietary composition, degree of energy deficit, compliance with the prescribed dietary regimens, and extract preparation/composition. Therefore, results look promising, but more research is needed to determine the effectiveness of pulse extract preparations. In addition, the relevance of these trials to consumption of whole pulses is uncertain. As mentioned earlier in this review, the activity of α-amylase inhibitor is thought to be destroyed during cooking and/or processing (46), although low levels of activity may remain (47). Few studies have been conducted on the effects of repeated consumption of processed/cooked pulses and other legumes, which may contain some low level of α-amylase inhibitor activity; therefore, this is an area that could be further researched.

![Figure 2](image-url)  
*Figure 2* Estimated median (131,132) or mean (82) legume intake of U.S. adults aged ≥19 y. The weighted average is based on the following sample sizes: n = 2005 men and 1904 women (132), n = 9317 adults (131), and n = 8229 adults (82). Estimates are based on either 1-d intake in NHANES 1999–2002 (82,131) or 2-d intake in NHANES 2003–2004 (132) (1 c = 240 mL).
Pulses in the U.S. diet

Based on recent analyses of dietary intake data from the NHANES, few U.S. adults consume pulses in their usual diet. The proportion of U.S. adults estimated to consume pulses or legumes over 1–2 d varies from 8–30%, depending on the data set used [NHANES 1999–2002 (82,131) vs. NHANES 2003–2004 (132)], the number of days of intake available (1 in NHANES 1999–2002 and 2 in NHANES 2003–4), and the type of legume analyzed, i.e. dried beans (82), nonsoy legumes (131), or legumes including soy beans and green beans (132). None of the estimates appear to have included food products that may contain pulse fractions such as pea fiber in baked goods and pasta.

The USDA-recommended amount of legume consumption for most adults aged 19 y and older is 3 c/wk, with the exception of women aged 51 y and older for which the recommendation is 2.5 c/wk (133). Perhaps not surprisingly, pulse consumption in the US is markedly below the recommendation (Fig. 2). The weighted average intake of legumes based on the available studies (82,131,132) is ~0.15 c/d (36 mL), which is ~58–65% lower than the recommended amount. Kimmons et al. (132) estimated that of the 30% of adults who do consume legumes, only about 40–45% of them achieved at least the recommended intake.

There are numerous factors that determine food choices, including, taste, cost, convenience, and nutrition (134,135). In the case of pulses and soybeans, there are likely additional factors, including purported physiological effects (digestibility issues), cultural factors, habits (e.g. vegetarianism/veganism), and knowledge about how to incorporate them into everyday diets. A strong incentive to increase pulse consumption may be their low cost, particularly for a high nutrient-dense food. Drewnowski (136) recently reported that beans were among the top 5 classes of food having the highest micronutrient to price ratio. Indeed, according to U.S. national surveys, pulse consumption is highest among low-income populations. Households in the lowest quartile of income (<130% of poverty level) represent 19% of the U.S. population but consume 27% of all cooked, dried beans (137). Furthermore, there are differences in the type of bean consumed by income level, with lower-income individuals consuming primarily pinto and lima beans and high-income individuals consuming more black beans and garbanzos. Some of these differences may relate to cultural preference for certain beans among minority populations, who tend to have lower average income levels than Caucasians.

Palatability or taste preferences could be another factor determining the choice to incorporate pulses as a major part of one’s diet. Several studies have been conducted recently showing a general acceptability of foods incorporating pulses or pulse flours (59,62,138–140), although depending on the specific pulse and the population, the range of acceptability could vary widely (141). Simply increasing familiarity with pulses could also help to increase the likelihood they may be incorporated into a diet more regularly (142,143).

Digestibility issues and potentially adverse gastrointestinal effects of pulse consumption may also be of concern to many individuals. Few studies have included formal measures of gastrointestinal tolerance to pulse consumption. As reviewed by Veenstra et al. (144), moderate consumption tends to be well tolerated but tolerance decreases when pulse consumption reaches very high levels.

Conclusion and recommended future directions

Based on the few studies that have been conducted, there is some indication that pulses may help to increase satiety, at least in the short term, and weight loss during intentional energy restriction over a few weeks. However, additional, longer term (≥1 y), randomized controlled trials are needed in this area, including those that investigate the optimal dose of pulses for weight control balanced with other factors worth considering, such as any potential negative effects (e.g. gastrointestinal tolerance, phytate effects of mineral absorption). Studies on behavioral techniques to overcome barriers, perceived or real, to pulse consumption may be helpful to effectively increase pulse intake in individual diets and on a population-wide basis.

Acknowledgments

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Literature Cited


