

Carbohydrates, Dietary Fiber, and Resistant Starch in White Vegetables: Links to Health Outcomes^{1,2}

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ABSTRACT

Vegetables are universally promoted as healthy. Dietary Guidelines for Americans 2010 recommend that you make half of your plate fruits and vegetables. Vegetables are diverse plants that vary greatly in energy content and nutrients. Vegetables supply carbohydrates, dietary fiber, and resistant starch in the diet, all of which have been linked to positive health outcomes. Fiber lowers the incidence of cardiovascular disease and obesity. In this paper, the important role of white vegetables in the human diet is described, with a focus on the dietary fiber and resistant starch content of white vegetables. Misguided efforts to reduce consumption of white vegetables will lower intakes of dietary fiber and resistant starch, nutrients already in short supply in our diets. *Adv. Nutr.* 4: 351S–355S, 2013.

Introduction

Vegetables have historically had a place in dietary guidance because of their concentrations of vitamins, especially Vitamins C and A, minerals, including electrolytes, and more recently phytochemicals. Additionally, vegetables are recommended as a source of dietary fiber and resistant starch. Most countries have dietary recommendations that include vegetables (Table 1). Separating vegetables into groups is difficult. Orange vegetables are high in vitamin A, but so are dark green vegetables, including spinach and broccoli. Dividing vegetables into color categories makes for good menu planning, but does not predict nutrient content.

Vegetables rich in vitamin C, such as green peppers and white potatoes, belong in different vegetable categories. Corn, white potatoes, and dried beans are rich in starch. Sweet potatoes are also high in carbohydrates, but mostly sucrose, not starch. Dark green vegetables contain little or no

starch. The vegetable categories in the 2010 Dietary Guidelines for Americans (1) are listed in Table 2.

According to the Dietary Guidelines for Americans 2010, the American diet is low in potassium, dietary fiber, calcium, and vitamin D. Energy density and calorie intake are problems with the American diet. Typically, vegetables are low in energy density and good sources of dietary fiber and potassium, but the nutritional contribution of standard servings of vegetables varies widely (2).

Carbohydrates

Most energy in the diet comes from carbohydrates. Carbohydrates are the major source of energy in the diet. The Institute of Medicine recommends that 45–65% of total calories come from carbohydrates (3). Dietary Guidelines for Americans suggests consumption of carbohydrate-rich foods, including vegetables, fruits, grains, nuts, seeds, and dairy products. Dietary fiber and resistant starch are only supplied by carbohydrate-rich foods.

The sugar units present and how these units are chemically bonded to each other describe carbohydrates. Carbohydrate categories include sugars, starches, and fibers. Sugars occur naturally in fruits and milk products and are added to foods during processing or preparation. Sugars also preserve food and provide viscosity and texture to foods. The nutrition facts panel lists total sugars, but does not distinguish between intrinsic and added sugar (4).

Starches are many glucose units linked together. Grains, legumes, and vegetables provide starch in the diet. Most

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Table 1. National guidelines for vegetables: United Kingdom and the United States

Characteristic	Eatwell Plate (United Kingdom)	My Plate (United States)
Agency	Food Standards Agency/National Health Service	USDA
Number of food categories	5	6
Key messages	Try to eat plenty of fruits and vegetables	Increase vegetable and fruit intake Eat a variety of vegetables, especially dark-green and red and orange vegetables and beans and peas
Units	Portions ¹	Servings ²
Vegetable		3 cups/d
Vegetable and fruit	5 portions per day	
Vegetable	3 heaping tbsps of vegetables (raw, cooked, frozen, tinned); 3 heaping tbsps of beans and pulses (beans and pulses count a maximum of one portion a day); and a dessert bowl of salad	1 cup green salad; 1 baked potato; 1/2 cup cooked broccoli; 1/2 cup serving of other vegetable; 1/2 cup tomato juice
Serving examples		
Potatoes included?	No. Potatoes not included (considered starchy food)	Yes
Legumes included?	Beans and pulses count as only 1 portion a day, no matter how many one eats	Yes (protein category as well, but should only be counted in 1 category)
Intake estimates	Men: 3.5 portions; women: 3.8 portions	4.7 servings (NHANES 1999–2000)

¹ 80 g.² Cups.

starches are broken down to sugars by digestive enzymes, but some starches, such as those in legumes and whole grains, escape digestion. These “resistant starches” function similarly to dietary fiber in the large intestine (5). Carbohydrate fermentation in the gut produces hydrogen gas, which is absorbed quickly.

Fiber

Dietary fiber is the undigested and unabsorbed carbohydrate in the diet (6). These resistant carbohydrates may be fermented in the large intestine. Soluble fibers lower serum lipids, whereas insoluble fibers increase stool weight (7). This division of soluble and insoluble fiber is still used in nutrition labeling. Many fiber sources are mostly soluble, but still increase stool weight, such as oat bran and psyllium. Soluble fibers, including inulin, do not lower blood lipids. Most vegetables are concentrated in insoluble fiber, not soluble fiber (8). Exceptions to this generalization include cooked potatoes. The USDA Nutrient Database includes only total fiber (9); there are no official databases that include soluble and insoluble fiber. Lists of content of total fiber, insoluble fiber, and soluble fiber are compilations of data from the USDA, the published literature, and estimated values (8). Often the values for soluble and insoluble fiber do not add to total fiber or the values for soluble fiber were estimated by subtracting a literature value for insoluble fiber from a USDA value for total fiber.

Processing can either increase or decrease the fiber content of a vegetable. Peeling of vegetables will lower the fiber content (8). Cooking generally has negligible effect on fiber content. Cooking, in general, may even increase the fiber content of a product if water is driven out in the cooking process. Baking or other heat treatments (e.g., extruding) used in food processing also increase fiber content of the product, either by concentrating the fiber by removal of water or production of Maillard products that are captured as fiber in gravimetric methods.

Fibers include both dietary fiber, the fiber naturally occurring in foods, and functional fibers, which are isolated fibers that have a positive physiological effect. No analytical measures exist to separate dietary fiber and functional fiber, so the nutrition facts panel lists dietary fiber, which is actually total fiber.

Americans consume ~15 g of fiber per day, about the half recommended levels (6). Most commonly consumed foods contain from 1 to 3 g of fiber per serving. The major sources of dietary fiber in the American diets are white flour and potatoes, not because they are concentrated fiber, but they are widely consumed (6). Fiber is an accepted essential nutrient and intakes are low, so public health messages to increase fiber consumption are warranted.

Resistant starch

Some starch escapes digestion in the small intestine and on reaching the large intestine acts similarly to dietary fiber. The starch that is not digested is called resistant starch. Different subtypes of resistant starch have been described (10). Starch that is physically inaccessible to digestive enzymes is

Table 2. USDA food patterns: vegetable subgroups

Subgroup and examples
Dark green vegetables: all fresh, frozen, and canned dark green leafy vegetables and broccoli, cooked or raw (broccoli, spinach, romaine, collard, turnip and mustard greens)
Red and orange vegetables: all fresh, frozen, and canned red and orange vegetables, cooked or raw (tomatoes, red peppers, carrots, sweet potatoes, winter squash, pumpkin)
Bean and peas: all cooked and canned beans and peas (kidney beans, lentils, chickpeas, and pinto beans; does not include green beans or green peas)
Starchy vegetables: all fresh, frozen, and canned starchy vegetables (white potatoes, corn, green peas)
Other vegetables: all fresh, frozen, and canned other vegetables (iceberg lettuce, green beans, onions)

Table 3. Carbohydrate, total dietary fiber, insoluble dietary fiber, soluble dietary fiber, and resistant starch in white vegetables in standard servings¹

White vegetable	Serving	Carbohydrate ²	TDF ³	IDF ³	SDF ³	Resistant starch ⁴
Potatoes, boiled	1 med, 138 g	29	2.1	1.7	0.4	1.8
French fries	208 g	76	4.4	3.6	0.8	5.6
Onions, raw	1/2 cup, 80 g	7.5	1.5	0.9	0.6	—
Turnips, peeled, cooked	1 cup, 156 g	7.9	3.1	—	—	—
Mushrooms, white, raw	1 cup, 96 g	3.1	1.0	0.7	0.3	—
Cauliflower, cooked	1 cup, 67 g	4.1	2.3	1.9	0.4	—
White beans, cooked	1/2 cup, 90 g	23	5.6	5.3	0.3	3.5, 11.1 (12)

¹ IDF, insoluble dietary fiber; SDF, soluble dietary fiber; TDF, total dietary fiber.

² Data on carbohydrates and total dietary fiber from (9).

³ Data on insoluble and soluble dietary fiber content of vegetables from (11). No data found for turnips.

⁴ Data on resistant starch from (12). No data found for onions, turnips, mushrooms, and cauliflower.

called resistant starch type 1, found in whole grains and seeds. Starch that is resistant to digestion due to the nature of the starch granule is referred to as resistant starch type 2. This type of starch is found in raw potatoes, unripe bananas, some legumes, and high amylose starches such as starch obtained from high amylose corn. Resistant starch that forms from retrograded amylose and amylopectin during food processing is called resistant starch type 3. This starch is found in cooked and cooled foods such as potatoes, bread, and cornflakes. The fourth type of resistant starch, resistant starch type 4, is produced by chemical modification. Resistant starch intake by Americans is ~3 to 8 g per person per day (10). In their database of resistant starch values obtained from published literature, highest resistant starch values (>3 g/100 g cooked serving) were found for toasted Italian bread, pumpkin bread, corn flakes, muesli, puffed wheat cereal, rice square cereal, potato chips, raw bananas, white beans, and lentils. There are no standard databases on the content of resistant starch in common foodstuffs. Processed potato products were found to have the highest resistant starch content of foods in the Swedish market (11).

A nutritional comparison of white vegetables for total carbohydrate, fiber, and resistant starch is shown in **Table 3**. Vegetables are often not consumed raw, but are cooked, fried, or combined with other ingredients before consumption. Thus, although a boiled potato is a nutrient-dense food, a fried potato may contribute a significant amount of fat and sodium to the diet. Fiber values of common servings of white vegetables range from 1.0 to 5.6 g per serving. Common serving sizes of fruits and vegetables contain 1–5 g of fiber (6). Most of the fiber in white vegetables is insoluble fiber; in fact, white beans are mostly insoluble fiber, although usual dietary guidance suggests that dried beans are a rich source of soluble fiber (**Table 3**).

Resistant starch values are difficult to find in the scientific literature. Methods to measure resistant starch are not standardized; thus, large variation is seen. For white beans, 1 reference stated that white beans contained an average of 4.2 g of resistant starch in a 100 g serving (10), whereas another reference (11) listed the same size serving of white beans as having 11.1 g of resistant starch. Many explanations are possible for this large discrepancy such as the method of

analysis, cooking method, and difference in food measured. It is also not clear whether the resistant starch measures should be added to the total dietary fiber content of the food. Thus, values for resistant starch must be considered, at best, estimates.

Health benefits of vegetables

A wide range of plants is consumed by humans, including fruits, seeds, leaves, roots, and tubers (12). The compositional features of certain types of white vegetables are summarized in **Table 4** (12). Roots and tubers are important sources of energy as starch. As foodstuffs, roots and especially tubers can be time-consuming to collect, but can be stored for long periods.

Determining exposure to vegetables in epidemiologic studies

Generally, culinary custom dictates which plants are considered vegetables. Culinary definition misclassifies botanical fruits, for example, squash, tomatoes, and mature beans, which, despite being culinary “vegetables,” are botanical “fruits.” Mushrooms are technically fungi, but generally considered vegetables in diet planning. Additionally, vegetables can be raw, cooked, canned, pickled, or leafy green.

Table 4. Compositional features of legumes (white beans) and roots and tubers (potatoes, turnips)

Feature	Legumes	Roots and tubers
	<i>g/100 g edible matter</i>	
Water	74.6–80.3	62.3–94.6
Protein	5.7–6.9	0.1–4.9
Fat	1.0–1.5	0.1–0.4
Sugar	1.8–3.2	0.5–9.5
Starch	5.4–8.1	11.8–31.4
Dietary fiber	4.5–4.7	1.1–9.5
Energy, kcal	247–348	297–525
Micronutrient	B vitamins, vitamin C, potassium, magnesium, phosphorus, iron	Vitamin E, carotenoids, iron, potassium, calcium
Toxic constituents	Hemaagglutinins, lectins, trypsin inhibitors	Glycoalkaloids

Adapted from Ref. 15.

Vegetables are often consumed in mixed dishes such as soups, casseroles, and stews, making it difficult to measure total vegetable intake in epidemiologic studies. Published studies on 3 methods for counting fruits and vegetables in fourth grade students found that different counting methods yielded significantly different tallies of fruit and vegetable intake (13).

Scientific support that vegetable consumption improves health outcomes is limited (14). Examination of large prospective cohorts found no significant relationship between vegetable consumption and risk of chronic disease (15). No association was found for total vegetable consumption and breast cancer incidence in a meta-analysis of 8 prospective studies (16). Higher consumption of vegetables, whether consumed raw or processed, was protective against coronary heart disease incidence in a cohort in the Netherlands (17). Fruit and vegetable consumption and prospective weight change were measured in a European prospective study of cancer and nutrition. Baseline fruit and vegetable intakes were not associated with weight change overall in participants from 10 European countries (18).

Health benefits of white vegetables

Potatoes are a staple vegetable in many parts of the world. Unlike leafy green vegetables, potatoes are rich in starch and provide protein of high biological value (19). Potatoes are rich in vitamin C and potassium and provide dietary fiber, especially if the skins are consumed. Few prospective studies have examined the relationship between potato consumption and health. Some data from the Nurses' Health Study suggest that potatoes and French fries are linked to the risk of type 2 diabetes in women (20). Epidemiologic studies generally find an inverse relationship between carbohydrate intake and BMI, even when controlling for potential confounders (21). Other white vegetables are consumed in low amounts in published prospective studies, so no conclusions can be drawn on links to health outcomes. However, white vegetables do provide vitamins, minerals, resistant starch, dietary fiber, and phytochemicals in the diet.

Conclusions

White vegetables provide carbohydrate, dietary fiber, and resistant starch to the diet. Epidemiologic studies show that dietary fiber is linked to less cardiovascular disease and has a role in obesity prevention. Resistant starch is similar to dietary fiber, but may have unique protective properties in colon cancer prevention. Carbohydrate intake is generally found to be protective against weight gain, so the carbohydrate, fiber, and resistant starch content of white vegetables, including potatoes, is linked to positive health outcomes.

Because vegetable intake is so low in US studies, it is not possible to isolate the effects of any particular vegetable on health outcomes in these studies. Fiber is most concentrated in cooked vegetables because water is removed and fiber concentrated. Although dietary guidance is supportive of a more vegetarian eating pattern, including increased servings

of vegetables, the scientific support for these recommendations is mixed in an evidence-based review (22). Fiber is an accepted nutrient so public health messages to increase fiber consumption are warranted. Much of the fiber intake in the United States is provided by white potatoes, so efforts to reduce consumption of potatoes will decrease intake of both fiber and resistant starch and potentially be detrimental to public health.

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