

SUPPLEMENT

White Vegetables: A Forgotten Source of Nutrients

White Vegetables: A Forgotten Source of Nutrients: Purdue Roundtable Executive Summary^{1,2}

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ABSTRACT

Purdue University convened a scientific roundtable, "White Vegetables: A Forgotten Source of Nutrients," in Chicago, IL, June 18–19, 2012, to bring together experts to address the contributions of white vegetables, including potatoes, as sources of key nutrients and other microconstituents within a dietary pattern supporting health and wellness. This paper summarizes the meeting and supplement papers, including discussion among participants. The group of researchers identified areas of ambiguity regarding classification of vegetables for research and dietary guidance, future research needs, and the imperative to draw on that research to enhance evidence-based dietary guidance about white vegetables, including potatoes. U.S. dietary guidance encourages consumption of a variety of fruits and vegetables, including at least 1 serving of a dark green and 1 orange vegetable daily. However, no such recommendation exists for white vegetables, such as potatoes, cauliflowers, turnips, onions, parsnips, mushrooms, corn, and kohlrabi. Vegetable subgrouping approaches need to be considered in the context of nutrients of concern and low fruits and vegetable consumption. This Roundtable and supplement provide a substantial body of evidence to demonstrate how the inclusion of white vegetables, such as potatoes, can increase shortfall nutrients, notably fiber, potassium, and magnesium, as well as help increase overall vegetable consumption among children, teens, and adults in the United States. In so doing, these increases can help consumers to effectively and economically meet the recommended 2010 Dietary Guidelines for Americans vegetable servings and improve nutrient intake for all age and sex categories. Although inclusion of many types of vegetables in the diet improves nutritional adequacy, a priority public health message is to increase vegetable consumption. Potatoes appear to be a pathway to increased vegetable consumption, thereby helping to meet the recommended 2010 Dietary Guidelines for Americans servings for vegetables provided the forms served limit the amount of added salt and fat. Potatoes, in all forms, when consumed in MyPlate serving sizes, can be part of health-promoting dietary patterns. More research is needed to determine the health contributions of white vegetables as a source of nutrients and bioactive constituents and their bioavailability beyond the isolated components. *Adv. Nutr.* 4: 318S–326S, 2013.

Introduction

Government dietary guidance in the United States and Canada encourages consumption of a variety of fruits and vegetables, including at least 1 serving of a dark green and 1 orange

vegetable per day (1,2). However, no such recommendation exists for white vegetables, such as potatoes, cauliflowers, turnips, onions, parsnips, mushrooms, corn, and kohlrabi. The USDA MyPlate vegetable group is divided into subgroups, of which 2 are color based and 3 are not: dark green vegetables, red and orange vegetables, beans and peas, starchy vegetables, and other vegetables (3). Thus, under the current food grouping system, no subgroup exists for white vegetables; rather, they are spread among the subgroups that are not color based. The categorization "starchy" vegetables calls out 1 nutritional aspect of those foods, yet many of the vegetables in this category, a number of which are white, are important sources of other nutrients such as fiber, vitamin C, and potassium. The "other vegetables" subgroup also contains white vegetables, including cauliflower, onions, and turnips, as does the beans and peas subgroup.

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Vegetable subgrouping approaches need to be considered in the context of low intakes of fruits and vegetables in the United States. The 2010 Dietary Guidelines for Americans recommend at least 4.5 cups (1.1 L) of fruits and vegetables a day (2 cups of fruits and 2.5 cups of vegetables; 0.5 L and 0.6 L, respectively) based on a 2000-kcal diet (1). However, the average person in the United States consumes only 1.8 cups (0.4 L) of fruits and vegetables (0.7 cups of fruits and 1.1 cups of vegetables; 0.2 L and 0.3 L, respectively) per day (4). Thus, Americans are consuming less than half the amount of vegetables recommended in federal dietary guidance.

Since the Columbian Exchange, white vegetables, such as potatoes, corn, and dried beans, have been important, not only in the North American diet but also globally, and have played an essential role in providing essential nutrients and energy. Yet the current status of white vegetables, particularly the potato, in the diet of Americans, for whom obesity and its health consequences are of great concern, has become uncertain and sometimes maligned.

Purdue University convened a scientific roundtable, “White Vegetables: A Forgotten Source of Nutrients,” in Chicago, IL, June 18–19, 2012, to bring together experts to address the contributions of white vegetables, including potatoes, as sources of key nutrients and other microconstituents within a dietary pattern supporting health and wellness. The articles in this supplement reflect presentations given at the meeting. This paper summarizes the meeting and supplement papers, including discussion among presenters and discussants. Participants identified areas of ambiguity regarding classification of vegetables for research and dietary guidance, future research needs, and the imperative to draw on that research to enhance evidence-based dietary guidance about white vegetables, including potatoes.

Presenting at the conference were the following:

- G. Harvey Anderson, PhD, Professor, Department of Nutritional Sciences, University of Toronto, Toronto, Ontario, Canada
- Stephen Barnes, PhD, Department of Pharmacology & Toxicology and Targeted Metabolomics and Proteomics Laboratory, University of Alabama at Birmingham, Birmingham, Alabama
- Eric A. Decker, PhD, Professor, Department of Food Science, University of Massachusetts, Amherst, Massachusetts
- Janet King, PhD, Children’s Hospital Oakland Research Institute, Oakland, CA and University of California at Berkeley and Davis, California
- Rui Hai Liu, MD, PhD, Professor, Department of Food Science, Cornell University, Ithaca, New York;
- Joanne Slavin, PhD, RD, Professor, Department of Food Science and Nutrition, University of Minnesota, St. Paul, Minnesota
- Maureen L. Storey, PhD, Alliance for Potato Research and Education, McLean, Virginia
- Stella Lucia Volpe, PhD, RD, LDN, FACS, Department of Nutrition Sciences, Drexel University, Philadelphia, Pennsylvania
- Connie Weaver, PhD, Distinguished Professor and Head, Department of Nutrition Science, Purdue University, West Lafayette, Indiana, who also chaired the Roundtable

Discussants at the meeting were the following:

- Nick Bellissimo, PhD, Assistant Professor, School of Nutrition, Ryerson University, Toronto, Ontario, Canada
 - Johanna Dwyer, DSc, PhD, Professor, Tufts University School of Medicine, and Senior Scientist, USDA Human Nutrition Research Center on Aging at Tufts University, Boston, Massachusetts
 - Gary Foster, PhD, Director, Center for Obesity Research and Education, and Professor, Medicine and Public Health, Department of Medicine, Temple University, Philadelphia, Pennsylvania
 - Jean Goldberg, PhD, Professor of Nutrition, Hancock Research Center on Physical Activity, Nutrition and Obesity Prevention, Tufts University, Boston, Massachusetts
 - Judith Wylie-Rosett, EdD, RD, Professor and Head, Division of Health Promotion and Nutrition Research, Department of Epidemiology and Population Health, Albert Einstein College of Medicine, Yeshiva University, New York, New York
- Sylvia B. Rowe, SR Strategy, Washington, DC, served as facilitator for the roundtable discussions.

It is hoped that the information presented in this supplement contributes to greater understanding and interest in white vegetables and health and serves as an impetus for further research.

Roundtable highlights

The 9 roundtable presentations were interspersed with 3 discussion periods with reaction from discussion panels. Topics addressed at the roundtable included macronutrient and micronutrient content of white vegetables and health outcomes, the limitations of color as a measure of nutritional content, and functional attributes of fruits and vegetables. Specific to white potatoes, dietary guidance, dietary intake, nutritional contributions, and food chemistry and processing innovations for nutritional enhancement were addressed. At the end of the conference, the full group discussed key learning and research priorities. The presenters were each asked to submit manuscripts based on their presentations, for publication in this supplement. This section summarizes the key points of the articles.

Color as a measure of nutrient content and in dietary guidance

The program started with a keynote address from Stephen Barnes exploring color as a proxy for phytochemical and other nutrition content. Barnes et al. (5) suggest that color is not necessarily a guide to what or how much beneficial or toxic phytochemicals are present in what we eat. Plant-based foods contain, in addition to micro- and macronutrients, several classes of phytochemicals. In many cases, phytochemicals account for the (various) colors of foods. Although aesthetically pleasing, the colors of food may mislead the consumer as to the effective content of nutrients and phytochemicals.

Human vision is limited to a small window (390–765 nm) of the electromagnetic spectrum. For other creatures, being able to see in the ultraviolet range allows bees to locate the pollen-rich region of a flower, whereas others (e.g., a pit viper) can visualize their prey being “seen” in the infrared area of the electromagnetic spectrum.

Many important nutrients, such as vitamin C, have no absorbance in the electromagnetic spectrum range visible to humans. Therefore, the human eye cannot judge directly the vitamin C content of a food. Other nutrients for which color is not an accurate measure include potassium, dietary fiber, calcium, and vitamin D were identified as nutrients of concern in the 2010 Dietary Guidelines for Americans due to low levels of intake (1).

Color can be an indicator of certain phytochemicals, but not others. This is particularly true of the polyphenols, a broad class of compounds with antioxidant and other health benefits. Three major classes of phytochemicals in foods are colored: carotenoids (colors from yellow to red), chlorophylls (green), and anthocyanins (blue, purple, and red). The latter are a particular type of flavonoid in the general family of polyphenols, the majority of which are not colored. Thus, the authors point out that color-based dietary guidance is an inaccurate approach for overall flavonoid content, which will overemphasize the importance of anthocyanin-containing foods versus those containing colorless flavonoids.

Assessing the impact of phytochemicals in foods on human health depends on several factors. For instance, colorless phytochemicals in unprocessed foods may be lost during the cooking process because there is no visual guide to ensure their retention. In addition, all phytochemicals may be altered by the cooking process and their chemistry may determine their absorption by the gastrointestinal tract. Finally, extensive metabolism by phase I/II enzymes and by the gut microbiome may create compounds that the eye never gets to appreciate.

Over the course of the 2-d roundtable and in the subsequent articles, the participants struggled with the ambiguity of fruit vegetable classifications for research and dietary guidance. The actual name of the round table, "White Vegetables: A Forgotten Source of Nutrients," spurred discussion around what constitutes "white vegetables." King and Slavin (6) explore the strengths and weaknesses of various frameworks for vegetable classifications in research and dietary guidance, including color-based constructs. Emphasizing color as a marker for health-promoting constituents eliminates white vegetables such as cauliflower, jicama, kohlrabi, onions, parsnips, shallots, turnips, and white potatoes, a vegetable common to all ethnic groups and food cultures. Ambiguity in vegetable classifications affects the research database, which in turn influences dietary guidance. King and Slavin note that only potatoes were arbitrarily eliminated from the white vegetable and fruit group in a study of the colors of fruit and vegetables and the incidence of stroke. Considering the potassium content of potatoes and potassium's role in reducing blood pressure, including potatoes in the study may have resulted in further reductions in stroke risk associated with white fruit and vegetable consumption.

Energy and macronutrients: protein, carbohydrate, fiber, and resistant starch

Energy and macronutrient contributions and impact on health were addressed in several roundtable presentations.

In their natural state, white vegetables contain negligible amounts of fat, whereas protein, carbohydrate, fiber content, and resistant starch levels vary. However, prepared and processed forms can contain significant amounts of fat, thereby increasing energy. This section focuses primarily on macronutrients naturally occurring in white vegetables: protein, carbohydrates, fiber, and resistant starch, whereas fat is addressed in the section on food chemistry and processing.

Protein. King and Slavin (6) discuss nutritional contributions of potatoes, including protein. Although the protein content per gram weight of potatoes is relatively low compared with the 3 other major staples (pasta, rice, and corn flour or maize), the quality of the potato protein, which reflects the digestibility and the amino acid content, is high. The coauthors review research showing long-term consumption of potato protein is of sufficient quality to support growth in undernourished infants and children as well as to maintain nitrogen balance and body weight in adults.

Potato biological value, depending on the cultivar, is between 90 and 100 and very similar to the biological value of a whole egg at 100 and higher than soybeans (84) and legumes (73). Thus, the protein quality of potatoes is higher than that of any other heavily consumed plant protein.

The protein quality of a food is determined by its amino acid composition in addition to digestibility. Only 4 essential amino acids are likely to limit protein quality of mixed human diets: lysine, methionine, threonine, and tryptophan. Potato amino acid content exceeds the recommended levels for all 4 of these essential amino acids, demonstrating that potato protein is high quality. Compared with pasta, rice, and corn grits, potatoes are the only staple food meeting the lysine score. However, the sulfur-containing amino acids (methionine and cysteine) are lower in potatoes than the other common staple crops, and scientists are currently developing transgenic forms of potatoes that have higher levels of the sulfur amino acids.

Fiber. Slavin (7) describes the important role of white vegetables in the human diet, with a focus on the dietary fiber and resistant starch content of white vegetables. Vegetables include a diverse group of plant foods that vary greatly in content of energy and nutrients and supply carbohydrates, dietary fiber, and resistant starch to the diet. However, because overall vegetable intake is so low in U.S. studies, it is difficult to isolate the effects of any particular vegetable on health outcomes in prospective, cohort studies. Fiber intake, including resistant starch, is linked to lower incidence of cardiovascular disease and obesity. Although it is commonly posited that white vegetables supply mainly starch to the diet, Slavin notes that, in particular, white potatoes are rich in vitamin C, potassium, dietary fiber, and resistant starch. Thus, she states, "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."

American women and men consume an average of only ~15 g of fiber per day, respectively, which is far short of the suggested adequate intake levels (8). Slavin shows total fiber content for common serving sizes of white vegetables ranges from 1.0 to 5.6 g per serving. She points out that the fiber in cooked potatoes is predominantly soluble fiber, in contrast to most other vegetables in which fiber is mainly insoluble.

The physiological effects of soluble fiber are still emerging. Soluble fibers are considered to have benefits on serum lipids, whereas insoluble fibers are linked to laxation benefits. However, scientific evidence showing that soluble fibers lower cholesterol and insoluble fibers increase stool weight is not consistent (8). Many fiber sources are mostly soluble, but still increase stool weight, such as oat bran and psyllium. Other soluble fibers such as inulin do not lower blood lipids. Fibers vary greatly in physiological effect, and the solubility of the fiber does not predict physiological outcomes such as blood lipid lowering or improved digestive health.

Resistant starch. Slavin also discusses resistant starch, starch that escapes digestion in the small intestine. Whether resistant starch has unique benefits beyond those found with fiber continues to be debated. Values for resistant starch in white vegetables are difficult to find in the literature and are often the results of different methods of measurement.

Micronutrients: potassium and magnesium

Fresh and processed vegetables, as a category, contribute significant amounts of micronutrients: almost half of the vitamin C, about one fourth of the vitamin A and potassium, and $\geq 10\%$ of folate, magnesium, iron, and copper, according to food supply data from the USDA Economic Research Service analyzed by Storey and Anderson (9). Potassium and magnesium are both present in white vegetables and were explored in detail because potassium, as previously mentioned, has been identified as a shortfall nutrient, and widespread magnesium underconsumption may be related to increased chronic disease, suggesting that this mineral is an emerging nutrient of concern.

Potassium. Weaver (10) provides a comprehensive review of potassium and health. Studies show that only 2%–3% of the U.S. population had total usual intakes of potassium that meet adequate intake levels (11). The 2010 Dietary Guidelines Advisory Committee concluded that there was a moderate body of evidence for the association between potassium intake and blood pressure reduction in adults, which in turn influences risk of stroke and coronary heart disease (12). Evidence is also accumulating for the protective effect of adequate dietary potassium on age-related bone loss and on reduction of kidney stones. Benefits for blood pressure and bone health may occur at levels below current recommendations for potassium intake, but dose-response trials are needed to confirm this. Nevertheless, intakes considerably above current levels are needed for optimal health, and studies evaluating small increases in fruit and vegetable

intake on bone and heart outcomes for short periods have had disappointing results. In modern societies, Western diets have led to a decrease in potassium intake with reduced consumption of fruits and vegetables with a concomitant increase in sodium consumption through increased consumption of processed foods. Potatoes are the highest source of dietary potassium, but processed forms are often higher in salt. Low potassium-to-sodium intake ratios are more strongly related to cardiovascular disease risk than either nutrient alone. This relationship deserves further attention for multiple target tissue end points.

A substantial body of evidence has documented that in adults, as blood pressure rises, so does the risk of CVD, particularly coronary heart disease and stroke, which together are the leading causes of mortality in the United States (13). The Dietary Approaches to Stop Hypertension (DASH)-style diet is high in fruits and vegetables, and dairy products and is effective at reducing blood pressure (14). The DASH diet potassium content, which is at levels recommended by the Institute of Medicine, is thought to be the largest explanation of the benefit of this dietary pattern, although the increased level of magnesium, calcium, fiber, and other bioactive constituents may also contribute to lowering blood pressure.

Fruits and vegetables, especially the potato, are excellent sources of potassium and play important roles in protecting against hypertension and, perhaps, in improving bone health. The organic potassium salts in foods have a broad range of health benefits to the heart, kidney, bone, and other tissues. Potassium chloride supplementation seemingly benefits blood pressure, but not bone. Public health messages to improve diet quality generally have potential for more far-reaching impacts than encouraging single nutrients in isolation.

Magnesium. Volpe (15) presents a review of magnesium in disease prevention and health. Magnesium is the fourth most abundant mineral and the second most abundant intracellular divalent cation and has been recognized as a cofactor for >300 metabolic reactions in the body. Some of the processes in which magnesium is a cofactor include, but are not limited to, protein synthesis, cellular energy production and storage, reproduction, DNA and RNA synthesis, and stabilizing mitochondrial membranes. Magnesium also plays a critical role in nerve transmission, cardiac excitability, neuromuscular conduction, muscular contraction, vasomotor tone, blood pressure, and glucose and insulin metabolism. Because of magnesium's many functions within the body, it plays a major role in disease prevention and overall health. Low levels of magnesium have been associated with a number of chronic diseases including migraine headaches, Alzheimer's disease, cerebrovascular accident (stroke), hypertension, cardiovascular disease, and type 2 diabetes mellitus.

It has been reported that ~60% of adults in the United States do not consume the recommended daily allowance for magnesium. The lower intake of magnesium from a

larger proportion of the U.S. population may be related to the increased rate of chronic disease. Nonetheless, increased diseases attributed to magnesium deficiency have not yet been reported, perhaps because they have not been explored in the medical community and/or because they may be related to a magnesium insufficiency and not an overt magnesium deficiency.

Low magnesium status has been associated with chronic inflammatory stress conditions. This inflammatory response could play a role in obesity in humans because obesity has been characterized as having a chronic low-grade inflammation component and an increased incidence of a low magnesium status. It is this marginal to moderate magnesium deficiency, through aggravating chronic inflammatory stress, that may be contributing significantly to the occurrence of atherosclerosis, hypertension, osteoporosis, type 2 diabetes mellitus, and certain types of cancer.

Although magnesium is a rather ubiquitous mineral, no major food provides an extremely high amount of magnesium. The foods highest in magnesium include unrefined (whole) grains, spinach, nuts, legumes, and potatoes (tubers) (15). One medium baked potato provides 48 mg of magnesium or 12% of the Daily Value making it a good source of magnesium. Freedman and Keast (16,17) published 2 studies on consumption of white potatoes, including French fried potatoes, using merged data from NHANES 2003–2004 and 2005–2006. They reported that, among all groups of consumers, white potatoes (prepared in various ways) contributed to ~10% of the total daily intake of various vitamins and minerals, including magnesium. Thus, white vegetables that are prepared healthfully need to be taken into consideration when educating individuals on healthy nutrition options for magnesium intake.

Functional attributes of white vegetables

Glycemia and satiety. Anderson (18) reviews the effect of white vegetable consumption on glycemia, satiety, and food intake. In his paper, Anderson uses the term white vegetables to refer to vegetables that are white or near white in color and includes potatoes, cauliflowers, turnips, onions, parsnips, white corn, kohlrabi, and mushrooms (technically fungi but generally considered a vegetable). His review is based on the hypothesis that a singular focus on the effects of carbohydrate in white vegetables on blood glucose, as measured by the glycemic index, may lead to counterproductive dietary recommendations. The article examines the question: “what weight should be placed on glycemic index or postmeal glycemia in vegetables that have high nutrient to energy density ratios, are low in energy density compared with other mealtime carbohydrate sources and within a meal contributes to early satiation and lower food intake?” White vegetables vary greatly in their contribution to the energy and nutrient content of the diet and glycemia and satiety. As with other foods, the glycemic effect of many white vegetables has been measured. The results illustrate that values of glycemic index for white vegetables are highly variable and depend on co-ingested foods. Importantly, the

overall contribution of the white vegetable to the carbohydrate and nutrient composition of the diet and their functionality in satiety and metabolic control within usual meals should be considered in evaluating the value of a food or food group to health. Anderson concludes that application of the glycemic index in isolation to judge the role of white vegetables in the diet, and specifically in the case of potato as consumed in ad libitum meals, has led to premature and possibly counterproductive dietary guidance.

Liu (19) reviews the health-promoting compounds in fruits and vegetables, in particular, the phytochemical categories of phenolics (including flavonoids) and carotenoids. He notes that phenolic compounds are not limited to fruits and vegetables with bright colors. For example, potatoes contain substantial amounts of phenolics, including flavonoids (quercetin and kaempferol), phenolic acids (gallic acid, chlorogenic acid, and caffeic acid), and contribute 25% of vegetable phenolics in the American diet, making potatoes the largest contributors among 27 vegetables commonly consumed in the United States. The hypothesis that regular consumption of fruits and vegetables (as well as whole grains) is associated with reduced risk of chronic diseases is based primarily on epidemiologic studies. Accumulating evidence suggests that the health benefits of fruits and vegetables are attributed to the synergy or interactions of bioactive compounds and other nutrients in whole foods, which may be why clinical trials with individual supplements have shown mixed results. This points to a varied diet, rich in plant-based foods, being advantageous to dietary supplements.

Nutritional contributions from potato intake

Storey and Anderson (9) examine total vegetable, white potato, and French fried potato consumption among children, adolescents, and adults 2+ y of age using 2009–2010 NHANES. They also assess average energy, potassium, and dietary fiber intakes. Mean energy intake for the population 2+ y, as a whole, was 2080 kcal/d. White potatoes provided ~3%–4% of total energy. French fried potatoes provided, on average, ~1.5% of total energy. White potato consumers ate significantly more total vegetables and more potassium than did nonconsumers. White potatoes provide a higher proportion of total potassium and dietary fiber intakes than the energy provided. For example, among 14- to 18-y-old consumers, white potatoes provided ~23% of dietary fiber, 19%–20% of potassium, but ~11% of total energy. The nutrient-dense white potato may be an effective way to increase total vegetable consumption and potassium and dietary fiber intake.

Low intake of vegetables, especially low intake of white potatoes, has negative consequences for achieving the adequate intakes of potassium and dietary fiber. The research of Storey and Anderson using NHANES 2009–2010 (9) confirms that vegetable intake, including consumption of starchy vegetables like the white potato, is ~50% below the recommendations made in the 2010 Dietary Guidelines for Americans (1). Their research also demonstrates that

among consumers, white potatoes contributed ~11% or less of average total energy among male consumers and 13% or less of average total energy among female consumers. However, white potatoes were significant sources of potassium and dietary fiber. In general, white potatoes contributed >18% of potassium intake for 11 of the 16 age/sex groups and >13% of potassium for the other 5 groups. More than 20% of dietary fiber was delivered by white potatoes to the diets of 6 of the 8 age groups among male consumers and 14%–26% dietary fiber to the diets among female consumers, on average. Consumers of white potatoes, on average, consumed significantly more potassium than did nonconsumers; however, there was little or no significant difference in mean intake of dietary fiber between consumers and nonconsumers of white potatoes. The analysis of Storey and Anderson of the NHANES 2009–2010 data confirms previous studies that white vegetables are affordable sources of many nutrients, especially those identified by the 2010 Dietary Guidelines Advisory Committee as nutrients of concerns in the diets of US consumers, 2 y of age and older.

The analysis of Freedman and Keast (17) of merged data from NHANES 2003–2004 and 2005–2006 showed that among children and adolescents who consumed these foods, white potatoes, French fried potatoes, and oven-baked fries contributed <10% of energy and <5% of total daily sodium intake, but 10% or more of the daily intake of vitamin B-6, potassium, and copper. Among adults 19+ y, Freedman and Keast found that ~35% of adults consumed white potatoes; ~12% consumed French fried potatoes (16). Potatoes provided <3% of sodium on the day that they were consumed, but ~14%–16% of dietary fiber, 17% of potassium intake, and ~about 10% of magnesium. On the day that French fried potatoes were consumed, these foods provided 10% or less of total energy and ~4% of dietary sodium, but 14%–16% of potassium and 16%–20% of dietary fiber intake by adults. Overall, analysis of NHANES cross-sectional data for both adults and children showed that on the day of consumption, white potatoes, including French fries, provided shortfall nutrients and nutrients of public health concern (dietary fiber, potassium, folate, magnesium, vitamins B-6, C, and K), within mean energy intakes consistent with mean estimated energy requirements.

Food processing and food chemistry

Despite the existence of many positive nutrients in potatoes, the popular press has recently aligned potatoes, and particularly fried potatoes, with an unhealthy diet. Decker and Ferruzzi (20) examine the impact of cooking and other food-processing operations on the nutritional content of potatoes. In addition, they explore the wide variation in the fat content of fried potatoes, depending on cooking method, and the potential of new food-processing technologies to improve the nutritional content of cooked potatoes. To date, these efforts have focused on developing technologies to both preserve the nutritional value of the raw product and improve the profile of finished “processed” products

by altering both macronutrient profile and micronutrient content through food chemistry and processing approaches.

Traditional processing and preparation methods (peeling, boiling, frying, and baking) can have a significant adverse impact on the overall nutritional quality of white potato products including loss of key micronutrients, adsorption of fat, and conversion of natural resistant starch into highly digestible starch. However, evidence suggests that preparation and processing methods can mitigate these less desirable outcomes and even enhance nutritional profiles. For example, techniques including oven baked par frying can significantly reduce fat content and enhance retention of sensitive nutrients often lost in immersion frying. Also application of food ingredient technologies such as hydrocolloid coatings to limit fat absorption and processing technologies such as vacuum frying, centrifugal draining, and controlled dynamic radiant frying have been applied to reduce fat content and improve the overall nutritional profile of fried potato products. Furthermore, technologies are being developed to enhance resistant starch and fiber content of potato products including use of potato skins and cooling post-processing. The approach to developing and applying new food technologies to improve the nutritional content of cooked potatoes offers the potential to generate improved potato products with enhanced nutritional profiles.

Discussion

The 9 roundtable presentations were interspersed with 3 discussion periods with reaction from discussion panels. At the end of the conference, the full group discussed key learning and research priorities. This section summarizes recurring themes and consensus that arose from the Roundtable as well as research gaps identified in this supplement’s articles.

Two central themes emerged from the Roundtable, both aimed at closing gaps:

1. How can the distance be narrowed between actual vegetable consumption and dietary guidance goals?
2. What is missing in the knowledge base concerning white vegetables and health?

Participants identified areas of ambiguity regarding classification of vegetables for research and dietary guidance. The lack of clarity and consistency in vegetable classifications affects the research database, which in turn affects dietary guidance.

Roundtable participants identified several key areas for future research needs to gain better understanding of the following:

1. The role of white vegetables in overall health and chronic disease risk reduction
2. Nutritional and other functional attributes of white vegetables, including technology applications in production and processing
3. Consumer perceptions and behaviors concerning white vegetables

Dietary guidance and vegetable consumption

Science is emerging on the high satiety value and functional attributes of white vegetables (potatoes, mushroom, onion, parsnips, etc.). Studies demonstrate these food choices can economically address nutrients of concern (potassium, dietary fiber) specified in the 2010 Dietary Guidelines for Americans. White vegetables, including white potatoes, provide important nutrients in the diet and deserve a positive position in dietary guidance.

Potatoes are often left out of the vegetable category in food guidance because of their purported association with higher fat diets. Yet white potatoes are a good source of several shortfall nutrients—potassium, magnesium, fiber, and vitamin B-6, and as consumed, provide ~3%–4% of total energy (9). French fried potatoes provide, on average, ~1.5% of total energy (9). Potatoes should be counted as a vegetable in food guidance systems. In fact, they had their own category in the 1933 USDA food guidance system because of their important contribution to nutrient intake (21).

In addition to falling within the definition of a vegetable, the white potato is also a staple food that is eaten routinely. Its high-carbohydrate, energy-dense composition puts the white potato in the category of a staple, whereas its classification as a tuber or root vegetable puts it in the vegetable category. Hence, the white potato is unusual in that it is a vegetable that is also a staple. The white potato is all the more unique because people who consume this tuber also have a higher intake of vegetables. Further, the emphasis on plant-based dietary patterns in the 2010 Dietary Guidelines for Americans presents an imperative to identify plant sources of high-quality protein, such as potatoes.

Areas for future research

The role of white vegetables in overall health and chronic disease risk reduction

Currently data are sparse regarding white vegetable (including potato) consumption and chronic diseases, such as obesity, diabetes, cancer, cardiovascular disease, and osteoporosis. Epidemiologic evidence exists, but those findings have not yet been confirmed through randomized clinical trials. Because vegetable intake is so low in U.S. studies, it is difficult to isolate the effects of any particular vegetable on health outcomes in prospective, cohort studies. Existing data from trials, such as DASH could be examined to assess consumption of white vegetables and outcomes. NHANES data on white vegetable consumption and blood pressure and BMI should also be examined.

Epidemiologic studies support that dietary fiber intake is linked to less cardiovascular disease and probably has a role in obesity prevention. Whether resistant starch has unique benefits beyond those found with fiber continues to be debated. There is a need to better elucidate the physiological and health impact of soluble and insoluble fiber and resistant starch.

Weaver (10) identified research needs concerning potassium consumption and chronic disease risk reduction. Low potassium-to-sodium intake ratios are more strongly related

to cardiovascular disease risk than either nutrient alone. This relationship deserves further attention for multiple target tissue endpoints. Clinical trials that are sufficiently large and of sufficiently long duration are needed for most of the health benefits attributed to potassium intake to establish causal relationships and dose response to guide public health decisions. Large long-term trials of potassium as organic salts and food at levels of ~90 mmol/d are needed to confirm benefits to bone. Understanding the role of the skeleton in responding to metabolically produced acid excess and the hypocalciuric effects of potassium organic salts requires mechanistic studies. In patient populations, trials are needed to determine the effect of potassium intake on hypertensive renal disease. The inability to accurately assess dietary intakes makes it impossible to refine potassium recommendations from observational studies. Future trials may show that potassium benefits occur at intakes below the current recommendations of 4700 mg/d.

Volpe's review (15) highlighted areas where magnesium has been shown to improve symptoms of migraine headaches, Alzheimer's disease, cerebrovascular accident (stroke), hypertension, cardiovascular disease, and type 2 diabetes mellitus, and she also indicated where more research is needed. Additional studies with larger sample sizes are required to further elucidate magnesium's effect on health. Longer term, prospective studies using similar amounts and types of magnesium supplementation are also needed to definitively establish a dose-response effect and the best type of magnesium to use.

Nutritional and functional attributes of white vegetables, including technology applications

Research about the role of white vegetables and health requires consistency: in classification of vegetables, in identifying their presence in multi-ingredient packaged foods and in serving sizes. Nutrient and food consumption research also relies on accurate and complete databases. Several needs exist in this area. The total fat, saturated fat, and *trans* fat content of processed foods has changed in recent years to better align with dietary guidance (22,23). The USDA Nutrient Database needs to be updated to reflect those changes, and *trans* fat, currently missing for a number of processed foods, needs to be added. Further, databases for soluble and insoluble fiber, as well as resistant starch, in foods are incomplete. This impedes research understanding the health aspects of these food constituents.

It was noted at the Roundtable that the bioavailability of nutrients in potatoes, in particular, should be explored further. Potatoes contain fiber but without phytate. A question that remains to be answered is whether minerals are more bioavailable in potatoes than whole grains. The carbohydrate, fiber, and resistant starch content could also be explored further to better understand whether potatoes are physiologically different from other starch sources and other vegetables. For example, are there prebiotic components in potatoes and what are health effects? Plant breeding, genetic modification, and growing conditions have been cited as

potential approaches for enhancing the nutritional value of potatoes (5,6,18,24). Such research should be encouraged by the nutrition community.

Specific to French fried potatoes, food science research and technological applications could help improve understanding of their nutritional contributions and potentially enhance their nutritional profile while maintaining sensory properties. Such areas include nutrient bioavailability, transference of nutrients from frying oils, minimizing nutrient loss, and sodium and fat reduction strategies.

Beyond nutrients, additional research is needed addressing the role of functional attributes of white vegetables, such as glycemic and satiety effects and phytochemicals, within the context of overall diet and chronic disease risk reduction. Anderson (18) emphasizes that in terms of dietary guidance, contextual research regarding glycemia and satiety is more valid. Research on individual vegetables within the context of overall dietary patterns and impact on satiety is warranted. One example would be to design a study to observe total energy consumed in meals with and without potatoes and compare with meals containing other sources of starch. There is also a need to understand white vegetables and satiety with children, in addition to adults. Increasing evidence points to the synergistic effect of bioactive compounds in fruits and vegetables, and additional research on the health benefits of these foods is warranted.

Consumer perceptions and behaviors concerning white vegetables

Although starchy vegetables have been downplayed, even demonized, in some nutrition circles, attitudinal research is needed to understand how consumers view these foods. Potatoes are a culturally familiar, popular, inexpensive food among consumers. Yet, potato consumption has declined in recent years. Have consumer attitudes toward potatoes changed or are other influences at work?

Naturally occurring nutrition content varies in vegetables according to cultivars and growing conditions, and the same is true for potatoes. Similarly, the nutritional content of potato fries varies depending on whether they are baked or deep fried. As Decker et al. (20) note, changes in frying applications can reduce fat content of deep-fried potatoes. Deep fryers have been nearly eliminated in the school setting. This suggests these variances in products and settings could be better communicated by health professionals and policy makers so that consumers recognize they can make choices based on individual needs and preferences.

We need a better understanding of how white vegetables, in particular potatoes, influence healthier eating patterns. Is white vegetable consumption a marker for overall diet quality? Within DASH data, is potato consumption correlated with a DASH diet score (a measure of compliance)? Understanding how white vegetables, in particular potatoes, affect school meals is also important for policymakers. In the school setting:

- Is there less plate waste, when potatoes are on the plate?

- Do oven-baked potato fries drive participation in school meals?

- Do potatoes (fries) drive consumption of other vegetables?

We have much yet to learn about the contribution of white vegetables to the diet in terms of health. Epidemiologic studies rarely separate out the contribution of white vegetables from the whole vegetable category. We know that diets rich in fruits and vegetables lower risk of cardiovascular disease. Nutritional interventions more often use individual nutrients rather than whole foods. So, although we know that potassium salts lower blood pressure, we do not know whether potatoes, the highest food source of potassium, can reduce blood pressure. We do not even know the bioavailability of potassium and other important nutrients from white vegetables. We also tend to look at single health outcomes or single tissues. We need to measure the whole contribution a food group like white vegetables to health using as many outcomes as is feasible including benefits to heart, bone, gut, and kidney as well as satiety and glycemia.

Conclusion

This Roundtable and supplement provide a substantial body of evidence to demonstrate how the inclusion of white vegetables, such as potatoes, can increase notably fiber, potassium, and magnesium, as well as increase overall vegetable consumption among children, teens, and adults in the United States. In so doing, these increases can help consumers to effectively and economically meet the recommended 2010 Dietary Guidelines for Americans vegetable servings and improve nutrient intake for all age and sex categories.

More research is needed to determine the health contributions of white vegetables as a source of nutrients and bioactive constituents and their bioavailability beyond the isolated components. The available evidence suggests that health benefits of white vegetables merits evaluation beyond merely thinking of them as a plate “filler.” The current research and innovation to reduce added fat and salt to white vegetable products should continue to maintain the healthfulness of the natural forms.

Although inclusion of many types of vegetables in the diet improves nutritional adequacy, a priority public health message is to increase consumption of vegetable intake. Potatoes appear to be a pathway to increased vegetable consumption, thereby helping to meet the recommended 2010 Dietary Guidelines for Americans servings for vegetables. Although not a substitute for vegetables of color, potatoes, in all forms, when consumed in MyPlate serving sizes, can be part of health-promoting dietary patterns.

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