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Replacing Protein Foods for Canned Beans Increases Shortfall Nutrient Intakes and Improves Diet Quality in Adults

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ABSTRACT

Background: Limited research has assessed nutrient and diet quality implications resulting from the replacement of protein-rich foods with canned beans.

Objective: The purpose of the present modeling analysis was to examine shortfall nutrient intakes and diet quality when isocalorically substituting protein foods with canned beans, including kidney beans, black beans, chickpeas, and pinto beans.

Methods: A modeling analysis was completed in free-living American adults using data from What We Eat in American 2001-2018, the dietary component of the United States National Health and Nutrition Examination Survey.

Results: The isocaloric substitution of protein foods with 1 and 2 servings of canned beans daily to the US typical dietary pattern significantly improved shortfall nutrient intakes. Intake of dietary fiber increased by 30% and 51%, respectively, with replacement of protein foods with 1 and 2 serving of canned beans, relative to the US typical dietary pattern ($p<0.0001$). Intake of iron, magnesium, potassium, and folate increased in the range of approximately 6-7% and 10-13% with replacement of protein foods with 1 and 2 servings of canned beans compared to the US typical dietary pattern ($p<0.0001$). Isocaloric substitution of protein foods with 1 and 2 servings of canned beans with the US typical dietary pattern led to 12% and 15% higher total Healthy Eating Index-2015 scores, respectively ($p<0.0001$).

Conclusions: Replacing commonly consumed protein foods with canned beans significantly increased shortfall nutrient intakes and improved diet quality. Greater canned bean consumption should be considered within future dietary recommendations as a strategy to promote nutrient intake shortfalls and improve deficits with current diet quality scores.

Keywords: canned beans; shortfall nutrients; diet quality; protein;

Introduction

Previous and current United States (US) Dietary Guidelines for Americans (DGA 2020-2025), have consistently encouraged greater consumption of beans within a defined healthy dietary pattern, due to the relatively low energy contribution and a high nutrient density profile.[1,2] The recent release of the Scientific Report of the 2025 Dietary Guidelines Advisory Committee (2025 DGAC) further promotes greater bean consumption for Americans.[3] Indeed, 2025 DGAC has been highly supportive of substitution or replacement of saturated fat-rich foods with a variety of plant-based foods, including plant-based protein-rich foods like beans, peas and lentils to reduce risk of cardiovascular disease.[3] Beans of all varieties, including canned beans, represent a nutrient-dense food option to not only align with DGA 2020-2025 and 2025 DGAC recommendations, but also may help close gaps in meeting nutrient recommendations for nutrients of public health concern and overall shortfall nutrient intakes as identified by DGA 2020-2025 and previous dietary guidelines.[1,2] For approximately 120 kcal, a 100 g serving of canned red kidney beans contains 9 g protein, 0.6 g total fat, 25 g carbohydrate, 8 g dietary fiber, 433 mg potassium, 50 mg magnesium, 311 mg sodium, 2 mg iron, and 39 µg folate, DFE.[4] A recent panel of experts examining the evidence surrounding carbohydrate food quality reported fruits, vegetables, beans and other legume products had the highest quality carbohydrate scores. This is predominantly due to the contribution of greater dietary fiber and potassium levels and reduced amounts of sugar and sodium levels.[5-7] Beans, peas, and lentils are unique foods in that they can be considered a part of the protein foods group as well as the vegetable group. DGA 2020-2025 has previously stated "shifts are needed within the protein foods group to add variety and selecting from the seafood subgroup or the beans, peas, and lentils subgroup more often could help meet recommendations while still ensuring adequate protein consumption.[2]

Bean consumption in Americans remains minimal in American children and adults, with about 1 in 5 individuals at or above recommendations for beans, peas and lentils.[2] Recent intake data show that beans, peas, and legumes are consumed in relatively small amounts, at an average of 0.1 cup eq/day and canned beans account for approximately 75% of units sold at US retail, outselling other forms by roughly 4:1.[8,9] Concurrent to canned beans representing the majority of bean intake, limited evidence is available on the nutritional contribution of canned bean products in American dietary patterns. The consumption of canned and non-canned beans in American adults has been previously associated with reduced systolic blood pressure relative to non-consumers of beans, parallel to greater daily sodium intakes. Similarly, consumption of a variety of beans was significantly related to higher shortfall nutrient intakes, lower discretionary fat and added sugar intake, and improved weight-related variables, in comparison to non-bean intake.[10] Recent analyses identifying bean dietary patterns of consumption in adults further demonstrated relationships with nutrient intakes, such that bean consumption was associated with higher intake of several shortfall nutrients, including dietary fiber, calcium, magnesium, potassium, iron, folate, and choline, when compared to non-bean consumption. Further, adults including beans as part of their typical dietary pattern had elevated total diet quality scores.[11]

Historical diet quality scores in US dietary patterns are well below authoritative recommendations, despite amassing data substantiating greater pulse, vegetables and fruit consumption to support diet quality and help promote longevity.[1,3,12-14] A recent modeling analysis has further considered the implications of replacing pulses (i.e., canned and non-canned combined) for other foods routinely consumed in the DGA 2020-2025 recommended Healthy U.S.-Style Dietary Pattern. Indeed, adding approximately ¼ cup of pulses per day to replace one ounce per day of protein foods led to a nearly 14% increase in dietary fiber intake.[15] Similarly, the addition of approximately ¼ cup of pulses per day to substitute for one ounce of refined grains led to substantial increases in several shortfall nutrients,

including dietary fiber, potassium and magnesium.[15] While this work demonstrated numerous benefits associated with substitution of protein foods and grain foods with pulses within the recommended Healthy U.S.-Style Dietary Pattern, the analysis did not focus on benefits resulting from canned beans or how such substitution can have an impact on the US typical dietary pattern (i.e., a representation of how Americans typically consume foods and beverages) and total diet quality.

As research is beginning to show numerous nutrient and diet quality benefits associated with various types of canned and dry bean consumption, limited data are available to assess the nutritional contribution of canned bean consumption alone in American dietary patterns. In particular, evaluating the shortfall nutrient intake and diet quality impact from substitution of routinely consumed protein foods with plant-based protein-rich foods in the typical US dietary pattern remains a void in the scientific literature. Thus, the purpose of the present modeling analysis focused on examining the isocaloric replacement of protein foods in the US typical dietary pattern with protein-rich canned beans to assess associations with shortfall nutrient intakes and diet quality in adults.

Methods

UNITED STATES NATIONAL HEALTH AND NUTRITION EXAMINATION SURVEY

The present modeling study represents a secondary analysis which used observational data from the United States National Health and Nutrition Examination Survey (NHANES), which is a continuous study directed by the Centers for Disease Control and Prevention (CDC). The NHANES dataset is a cross-sectional, nationally representative sample of free-living American individuals, of which includes infants, children and adult representation.[16] The data represented individuals from all four regions of the United States (Northeast, Midwest, South, and West).

Ethical protocols, including informed consent from study participants have been previously obtained, approved and documented by the CDC ethic boards. The current analysis amalgamated 9 NHANES datasets, thus spanning nearly 20 years of dietary recall data (i.e., NHANES 2001-2002, NHANES 2003-2004, NHANES 2005-2006, NHANES 2007-2008, NHANES 2009-2010, NHANES 2011-2012, NHANES 2013-2014, NHANES 2015-2016, and NHANES 2017-2018[17]. Energy and nutrients assessed stem from the U.S. Department of Agriculture (USDA) Food and Nutrient Database for Dietary Studies (FNDDS) database for NHANES.[18] The FNDDS databases determine food and beverage nutrient values in What We Eat in America (WWEIA), which represents the dietary intake component of NHANES. The collection procedure for WWEIA involves use of the Automated Multiple Pass Method (AMPM), representing a dietary collection tool that provides a valid, evidence-based approach for gathering data for national dietary surveys. Accuracy, effectiveness, and efficiency of the AMPM method has been comprehensively described and previously published.[19]

STUDY PARTICIPANTS

Dietary recall data were obtained for individuals ≥19 years of age, with exclusions for incomplete data (N=44,574). Data interpreted to be reliable comprised completed 24-hour recalled dietary data. Pregnant and lactating females were not included in the analysis.

STATISTICAL AND MODELING ANALYSES

A canned bean composite based on all United States Department of Agriculture (USDA) identified canned bean foods from WWEIA 2001-2018 was used to determine energy and nutrient contribution from canned beans (see Table 1) and used to model replacement of protein foods into the typical US dietary pattern of adults. Canned beans were defined as USDA category 2802 with 'canned' in the description notes. All refried beans listed by USDA were excluded from the analysis. The nutrient amounts for the canned bean composite were the weighted averages per reference amount customarily consumed (RAAC) summed overall all intakes in the bean definition category. Bean consumption included

the principal type of canned beans routinely consumed by Americans and included kidney beans, black beans, chickpeas, and pinto beans, with exclusion of soybeans. Serving sizes were based on RAAC. Similarly, a protein foods composite based on all foods within the USDA protein foods category (i.e., meats, poultry, eggs, seafood, nuts, seeds and soy products) of WWEIA 2001-2018 was calculated and presented in Table 2. Diet quality was examined using USDA's Healthy Eating Index 2015 (HEI-2015) –a validated dietary tool that measures conformance to US dietary guidance.[20,21] Further details and strengths of the HEI-2015 diet quality scale remain well-documented and thoroughly reported within the scientific literature.[21,22]

To complete our objectives, the United States Department of Agriculture (USDA) dietary modeling approach was used.[23] The USDA's Food Patterns provide amounts of foods from the five major food groups and subgroups, including (1) Fruits; (2) Vegetables (dark green, red, and orange, beans and peas, starchy, and other); (3) Dairy (milk, cheese, yogurt, includes calcium-fortified soy beverages); (4) Grains (whole grains and refined grains); and (5) Protein Foods (meats, poultry, and eggs; seafood; nuts, seeds, and soy products). The USDA generates food item clusters of the defined food groups and then calculates energy and nutrient amounts that would be obtained by consuming different foods within each food group. The USDA then creates dietary patterns with the suggested levels of consumption of each food group/sub-group and confirms that the patterns meet the energy and nutrient needs for the various age groups within the American population. For the present analysis, the protocol made changes to the protein foods consumed (decrease other protein food amounts and increase bean consumption). The following modeling scenarios were used to determine, nutrient intakes and diet quality outcomes:

Baseline: No modifications to the typical US dietary pattern (i.e., no isocaloric replacements of protein foods with canned beans)

Model 1: Isocaloric replacement of 1 serving of protein foods with 1 serving of canned beans (i.e., ½ cup of canned beans) in the US typical dietary pattern to assess nutrient intakes

Model 2: Isocaloric replacement of 2 servings of protein foods with 2 serving of canned beans (i.e., 1 cup of canned beans) in the US typical dietary pattern to assess energy and nutrient intakes

Model 3: Isocaloric replacement of 1 serving of protein foods with 1 serving of canned beans (i.e., ½ cup of canned beans) in the US typical dietary pattern to assess total and sub-component diet quality scores

Model 4: Isocaloric replacement of 2 servings of protein foods with 2 serving of canned beans (i.e., 1 cup of canned beans) in the US typical dietary pattern to assess total and sub-component diet quality scores.

Statistical Analysis System (SAS) software (Version 9.4, SAS Institute, Cary, NC, USA) was used to generate all statistical processes. The investigation used day 1 dietary survey weights to develop nationally representative estimates for all adults, along with adjustment for the complex sample design of the database. Covariate adjustments were not required since sample weights adjusted for typical demographic variables. Means (± standard errors (SE)) for daily energy, nutrient intakes and HEI-2015 total and sub-component scores were determined and t-tests were used to assess differences at baseline and all modeling analysis.

Results

CANNED BEAN ENERGY AND NUTRIENT COMPOSITE

Using canned bean data collected within NHANES, the identified canned bean composite contributed approximately 138.5 kcal (90 g serving). Table 1 presents the nutrients contributed from canned beans. The canned bean composite further demonstrates the nutrient density of canned beans, such that

canned beans a significant source of several shortfall nutrients (i.e., magnesium, iron, dietary folate and choline) and three of the four DGAC nutrients of public health concern (i.e., dietary fiber, potassium, calcium). Canned beans also contribute negligible amounts of total sugar and no added sugar per 138.5 total calories, while concurrently being a substantial source of protein. While sodium contribution is elevated, the sodium to potassium ratio is greater than 1.0, thus, falling into recommendations set forth by the American Heart Association to add more potassium-rich foods to dietary patterns to blunt the effects of sodium.[24]

Table 1: Nutrients Sourced from Canned Beans in Adults

Nutrient	Amount	Nutrient	Amount	Nutrient	Amount
Carbohydrate (g)	21.0	Total Sugar (g)	1.3	Added Sugar (g)	0
Protein (g)	7.2	Calcium (mg)	51.4	Vitamin A RAE (mcg)	0.1
Total Fat (g)	3.2	Iron (mg)	2.2	Vitamin B6 (mg)	0.2
MUFA (g)	1.2	Potassium (mg)	372	Vitamin C (mg)	1.8
PUFA (g)	1.3	Sodium (mg)	261	Vitamin E (mg)	0.9
SFA (g)	0.5	Phosphorus (mg)	136	Niacin (mg)	0.6
Cholesterol (mg)	0.03	Zinc (mg)	0.8	Folate, DFE (mcg)	56.6
Dietary Fiber (g)	7.5	Magnesium (mg)	44.5	Choline (mg)	31.4

Bean composite sourced from US NHANES 2001-2018 datasets; includes canned beans (kidney, black beans, chickpeas and pinto beans) in US adults ≥19 years-old; MUFA=monounsaturated fatty acids; PUFA= polyunsaturated fatty acids; SFA=saturated fatty acids

PROTEIN FOODS ENERGY AND NUTRIENT COMPOSITE

The NHANES identified protein foods composite contributed approximately 157.3 kcal (68.6 g serving). Table 2 presents the nutrients contributed from all protein foods, without consideration for any bean products. The protein foods composite illustrates protein foods substantially contribute to intakes of protein and choline, but relative to canned beans, are lower in iron, potassium, magnesium and dietary folate. Protein foods also contribute greater amounts of monounsaturated, polyunsaturated, saturated and total fat compared to canned beans. Further, sodium contribution from the protein foods composite is greater than the canned beans composite, while potassium is greater in canned beans and lower in protein foods. This creates a sodium to potassium ratio in protein foods which is less than 1.0, thus, not meeting recommendations set forth by the American Heart Association.[24]

Table 2: Nutrients Sourced from Protein Foods Composite in Adults

Nutrient	Amount	Nutrient	Amount	Nutrient	Amount
Carbohydrate (g)	4.1	Total Sugar (g)	0.9	Added Sugar (g)	0.1
Protein (g)	13.4	Calcium (mg)	24.8	Vitamin A RAE (mcg)	26.2
Total Fat (g)	9.6	Iron (mg)	1.1	Vitamin B6 (mg)	0.2
MUFA (g)	4.0	Potassium (mg)	209	Vitamin C (mg)	0.4
PUFA (g)	2.0	Sodium (mg)	367	Vitamin E (mg)	0.8
SFA (g)	2.7	Phosphorus (mg)	148	Niacin (mg)	3.3
Cholesterol (mg)	71.0	Zinc (mg)	1.6	Folate, DFE (mcg)	17.0
Dietary Fiber (g)	0.7	Magnesium (mg)	22.3	Choline (mg)	46.5

Bean composite sourced from US NHANES 2001-2018 datasets; includes canned beans (kidney, black beans, chickpeas and pinto beans) in US adults ≥19 years-old; MUFA=monounsaturated fatty acids; PUFA= polyunsaturated fatty acids; SFA=saturated fatty acids

OSOCALORIC SUBSTITUTION OF PROTEIN FOODS WITH CANNED BEANS IN THE US TYPICAL DIETARY PATTERN AND NUTRIENT INTAKES

Modeling the isocaloric substitution of protein foods with the addition of beans to the diet significantly increased nutrients identified as 'nutrients of public health concern' by dietary guidelines (See Table 3).[1,2] Specifically, dietary fiber increased approximately 30% and 51% when protein foods were replaced with 1 and 2 serving of canned beans in the US typical dietary pattern (16.6±0.1 vs. 21.5±0.1 and 16.6±0.1 vs. 25.0±0.1, respectively; $p<0.0001$) when compared to the US typical dietary pattern consumed by adults. Similarly, potassium intake significantly increased approximately 6% and 10% when protein foods were replaced with 1 and 2 serving of canned beans in the US typical dietary pattern (2701±12 vs. 2862±12.4 and 2701±12 vs. 2976±12.4, respectively; $p<0.0001$). The isocaloric substitution of protein foods for canned beans in the US typical dietary pattern also resulted in significant improvements in DGA 2020-2025 shortfall nutrient intakes, including magnesium, iron, and folate DFE. Significant reductions in intake of protein, and total fat were also observed.

Table 3: Nutrient Intakes When Iso-Calorically Modeling the Substitution of Protein Foods with Canned Beans in the US Typical Dietary Pattern, Adults ≥19 Years-Old

Energy/Nutrient	US Typical Intake		Substitution of Canned Beans for Protein Foods in the US Typical Dietary Pattern					
			Servings = 1			Servings = 2		
	Mean	SE	Mean	SE	P-value	Mean	SE	P-value
Energy (kcal)	2164	7.2	2164	7.2	<0.0001	2164	7.2	<0.0001
Protein (g)	83.0	0.3	78.6	0.3	<0.0001	75.6	0.3	<0.0001
Carbohydrate (g)	259	1.0	274	0.9	<0.0001	285	0.9	<0.0001
Total Fat (g)	83.2	0.4	78.7	0.3	<0.0001	75.6	0.3	<0.0001
Dietary Fiber (g)	16.6	0.1	21.5	0.1	<0.0001	25.0	0.1	<0.0001
Iron (mg)	15.1	0.1	16.2	0.1	<0.0001	17.0	0.1	<0.0001
Magnesium (mg)	300	1.6	322	1.6	<0.0001	337	1.6	<0.0001
Potassium	2701	12	2862	12.4	<0.0001	2976	12.4	<0.0001
Sodium	3589	14	3537	13.7	<0.0001	3500	13.7	<0.0001
Folate, DFE (mcg)	536	3.2	573	3.2	<0.0001	598	3.2	<0.0001
Choline (mg)	335	1.7	317	1.6	<0.0001	303	1.6	<0.0001

SE=standard error; NHANES 2001-2018; N=44,574; 1 serving = ½ cup of canned beans; 2 servings = 1 cup of canned beans

ISOCALORIC SUBSTITUTION OF PROTEIN FOODS WITH CANNED BEANS IN THE US TYPICAL DIETARY PATTERN AND DIET QUALITY

Modeling the substation of protein foods with 1 and 2 servings of canned beans daily to the US typical dietary pattern significantly increased total diet quality, as assessed by USDA's HEI scale (Tables 4). Modeling the replacement of 1 serving of protein foods within the US typical dietary pattern with 1 serving of canned beans led to 12% higher total HEI score. Similarly, modeling the substitution of protein foods with canned beans resulted in a significant increase in total diet quality (i.e., 15% increase vs. baseline US typical dietary pattern). Overall, higher sub-component scores (i.e., greater consumption) in total vegetables, greens and beans, and seafood and plant proteins contributed to significantly better overall diet quality. Likewise, elevated scores (i.e., lower consumption) in sodium, refined grains and saturated fat further contributed to higher total diet quality scores.

Table 4: Healthy Eating Index Total and Sub-Component Scores When Iso-Calorically Modeling the Substitution of Protein Food Servings with Canned Beans in the US Typical Dietary Pattern, Adults ≥19 Years-Old

HEI Sub-Component	US Typical Intake		Substitution of Canned Beans for Protein Foods in the US Typical Dietary Pattern					
			Servings = 1			Servings = 2		
	Mean	SE	Mean	SE	P-value	Mean	SE	P-value
Total Vegetables	3.1	0.02	3.7	0.01	<0.0001	4.0	0.01	<0.0001
Greens and Beans	1.5	0.02	4.0	0.01	<0.0001	4.1	0.01	<0.0001
Total Fruit	2.1	0.02	2.1	0.02	NS	2.1	0.02	NS
Whole Fruit	2.0	0.03	2.0	0.02	NS	2.0	0.02	NS
Whole Grains	2.4	0.03	2.4	0.03	NS	2.4	0.03	NS
Dairy	5.0	0.03	5.0	0.03	NS	5.0	0.03	NS
Total Protein Foods	4.2	0.01	4.2	0.01	NS	4.3	0.01	<0.0001
Seafood and Plant Protein	2.3	0.02	4.1	0.01	<0.0001	4.2	0.01	<0.0001
Fatty Acid Ratio	5.0	0.03	5.2	0.03	<0.0001	5.3	0.03	<0.0001
Sodium	4.3	0.03	4.4	0.03	<0.0001	4.6	0.03	<0.0001
Refined Grains	6.2	0.03	6.3	0.03	<0.0001	6.3	0.03	<0.0001
Saturated Fat	5.9	0.03	6.6	0.03	<0.0001	7.0	0.03	<0.0001
Added Sugar	6.5	0.04	6.5	0.03	NS	6.5	0.03	NS
Total HEI Score	50.4	0.2	56.5	0.02	<0.0001	57.8	0.2	<0.0001

SE=standard error; NHANES 2001-2018; N=; NS=non-significance: 1 serving = ½ cup of canned beans; 2 servings = 1 cup of canned beans

DUSCUSSION

The isocaloric replacement of protein foods with 1 and 2 servings of canned beans daily to the US typical dietary pattern significantly improved shortfall nutrient intakes. Intake of dietary fiber increased by 30% (4.9g per day) and 51% (8.4g per day), with replacement of protein foods with 1 and 2 servings of canned beans, respectively, relative to the US typical dietary pattern. As dietary fiber has been identified as a nutrient of public health concern by DGAs, the current modeling demonstrates the dietary fiber value contributed from canned beans as fewer than 1 in 10 US adults meet fiber recommendations to maintain optimal digestive health and prevent chronic diseases, including cardiovascular disease, diabetes, obesity and certain cancers.[1,2] Our analysis further highlights the relevant influence canned beans portray in helping individuals close the gap on potassium intake shortfalls, especially with less than 5% of Americans meeting adequate intake.[25] Like dietary fiber, potassium has been designated as a nutrient of public health concern.[1,2] When replacing protein foods with 1 and 2 serving of canned beans in the US typical dietary pattern, potassium levels significantly increased by about 6 and 10%, respectively. The American Heart Association has previously stated "foods with potassium can help control blood pressure by blunting the effects of

sodium and the more potassium you eat, the more sodium you process out of the body."[24] When considering other shortfall nutrients, intake of iron, magnesium, and folate increased approximately 7% and 13% with replacement of protein foods with 1 and 2 servings of canned beans compared to the US typical dietary pattern. Finally, modeling the isocaloric replacement of protein foods with 1 and 2 servings of canned beans daily to the US typical dietary pattern significantly increased total diet quality, as assessed by USDA's HEI scale. Relative to the US typical dietary pattern, substituting 1 serving of protein foods with 1 and 2 servings of canned beans led to 12% and 15% higher total HEI score, with the majority of the total score stemming from higher scores in several HEI sub-components, including total vegetables, greens and beans, seafood and plant protein, and saturated fat.

The present study is aligned with previous analyses using data from NHANES in children and adult populations. Earlier work using data from NHANES 1999-2002, demonstrated various types of canned and dry bean consumption were associated with superior nutrient intakes and favorable health outcomes.[10] Indeed, when considering nutrients of public health concern as outlined by DGAC, irrespective of the type of beans consumed, bean consumption was associated with greater dietary fiber and potassium intakes versus non-bean consumption.[3] Similarly, when assessing baked bean consumption, subjects had higher intakes of several shortfall nutrients, including dietary fiber, potassium, magnesium, and iron compared to bean non-consumers. Baked bean consumption was associated with significantly lower systolic blood pressure versus non-consumption of baked beans, even though greater sodium intakes were observed in baked bean consumers. The authors also found greater intakes of dietary fiber, potassium, magnesium, iron and folate in individuals consuming a variety of beans, including pinto and kidney beans, relative to those avoiding beans. Reduced body weights, decreased waist circumferences and a 29% lower risk of having an elevated waist circumference were observed in bean consumers compared to non-consumers. When consumption of baked beans and variety beans were combined in the analysis, adult consumers had a 23% lowered risk of increased waist circumference and a 22% reduced risk of obesity relative to non-consumers[10]. More recent NHANES data using cluster analyses to identify various beans patterns which were associated with improved nutrient intakes and higher diet quality scores.[11] Indeed, adults consuming several different bean dietary patterns had higher intakes of several shortfall nutrients compared to no bean consumption, and greater intake of dietary fiber, potassium and calcium. All bean dietary patterns of consumption were associated with significantly higher diet quality scores, predominantly due to elevated scores from food groups encouraged by DGA, including total vegetables, greens and beans, seafood and plant proteins. Likewise, US typical dietary patterns that include additional servings of beans daily are associated with greater intake of several shortfall nutrients, including dietary fiber, magnesium, potassium, iron, and dietary folate. Furthermore, modeling 1 and 2 servings of canned and dry beans daily to the US typical dietary pattern significantly elevated total diet quality in both younger and older adults, suggesting that bean consumption in all age groups are likely to have considerable and beneficial public health outcomes.[26]

Peer-reviewed evidence demonstrating the nutrient and health benefits of bean consumption continues to accumulate in various populations. A recent dose-response analysis examining long-term (i.e., > 5 years) intake of certain foods and reported a 0.5% decreased risk of cardiovascular-related mortality for every 10 g increase in legume consumption per week.[27] While this may appear minimal, the reduction in mortality risk stems from one food item and a minimal increase per week. Further analyses should consider more practical and realistic consumption increases and cumulative risk reductions in mortality with the inclusion of other foods. Indeed, in the same dose-response study, researchers found a 4% reduced risk of cardiovascular-related mortality

following each 10 g increase in whole grain consumption per day. As well, accruing research is demonstrating the benefits associated with canned bean consumption. A Canadian clinical study explored adding canned beans to the routine diet of overweight and obese adults and found significant and positive metabolic effects. Specifically, significant reductions were seen in waist circumference in males and females consuming five cups of canned navy beans per week for 4 weeks, while significant lowering of heart rate, total cholesterol and LDL-cholesterol was only observed in males.[28] A randomized, crossover, multicenter trial in adults examined the cardiovascular effects of 4-week treatment of canned beans (i.e., bean type included pinto, navy, black, white kidney and dark red kidney beans) versus white rice. Total cholesterol and LDL-cholesterol were significantly decreased following 1 cup of canned beans, but not following 1 cup of white rice, suggesting that 1 cup of canned beans can have prominent effects in helping to significantly reduce cardiovascular disease risk.[29]

Diet quality in non-institutionalized US citizens has moderately improved during the last two decades, however, HEI scores demonstrate that diet quality gaps persist and significant improvements in diet quality scores are required to reflect national nutrition recommendations to promote nutrition and public health.[1-3] Key contributors to the total diet quality score include plant-based food groups, where greater consumption of foods like fruit, legumes and vegetables increase diet quality scores due to an abundance of evidence linking greater intake of these foods with reduced chronic disease risk and lower risk of mortality.[12-14,30] Similarly, the American Heart Association has encouraged greater consumption of high-quality, plant-based diets, rich in legumes, fruits and vegetables, while encouraging less animal-based diets as a strategy to help reduce risk of chronic diseases, including cardiovascular disease, cancer, diabetes and obesity.[24] Diet quality has routinely been related to weight-related outcomes in various populations.[12,30,31] Dietary patterns of inferior diet quality are routinely defined by reduced consumption of nutrient-dense foods, including beans, whole grains, fruits and vegetables, simultaneous to greater consumption of foods rich in calories, added sugars, sodium and saturated fats.[32] In analyses using data from the Canadian Community Health Survey, researchers observed an inverse relationship between diet quality indices and BMI. In particular, a 1-unit elevation in the Diet Quality Index total score was associated with a significantly lower BMI. Similarly, a 1-unit increase in the HEI-2010 total score was also linked to a significant decrease in BMI.[33] Higher diet quality scores resulting from greater consumption of legumes and other nutrient-dense foods were related to significant reductions in all-cause, coronary heart disease and cancer mortality rates in a Greek cohort of approximately 22,000 men and women. Indeed, a greater adherence to a Mediterranean diet was associated with 25%, 33% and 24% reduced risk of all-cause, coronary heart disease and cancer mortality, respectively.[30] Likewise, a cross-sectional analysis among post-menopausal Greek females further supports a relationship between diet quality and weight-related outcomes, such that greater adherence to the Mediterranean diet, characterized by increased consumption of legumes and high-fiber cereals were associated with significantly lower BMI, reduced waist circumference and decreased waist-to-hip ratio.[34]

The NHANES official protocols consist of nutrient intake and diet quality data being obtained from 24-hour dietary recalls, which rely on study participant memory. As such, limitations with the NHANES dataset, similar to limitations in observational research, have been documented consistently in the published literature.[35,36] The data collection process involves the use of validated procedures to help minimize research constraints, however, recalled information may encompass inaccuracies due to challenges, which can include bias due to memory deficits and/or reporting misrepresentation.[35-36] Nonetheless, an essential and unique advantage of the current public health research originates from the use of the NHANES dataset[16], which is a large and robust continuous survey that examines a

nationally representative sample of approximately 5,000 individuals yearly by highly-trained medical researchers and has historically been a valuable evidence-based source for helping to form beneficial nutrition and health policies for the American population.

Conclusions

The isocaloric replacement of protein foods with 1 and 2 servings of canned beans daily to the US typical dietary pattern significantly improved shortfall nutrient intakes, including dietary fiber, potassium, iron, magnesium, and folate. Further, modeling the isocaloric replacement of protein foods with 1 and 2 servings of canned beans daily to the US typical dietary pattern significantly improved total diet quality, such that, substituting 1 serving of protein foods with 1 and 2 servings of canned beans within the US typical dietary pattern led to 12% and 15%, respectively, higher total HEI score. The avoidance of beans within dietary patterns may lead to nutrient and public health consequences in adults and/or exacerbate current nutrient shortfalls. Dietary strategies involving the promotion of increased canned bean consumption within authoritative recommendations may prove favorable and help Americans improve overall health.

Declarations

ETHICS APPROVAL AND CONSENT TO PARTICIPATE:

Ethics approval/consents have been previously conducted via the Centers for Disease Control and Prevention and the Research Ethics Review Board at the National Center for Health Statistics.

CONSENT FOR PUBLICATION:

Not Applicable

AVAILABILITY OF DATA AND MATERIALS:

Publicly available US datasets were analyzed in the present study and can be found here https://wwwn.cdc.gov/nchs/nhanes. The NHANES datasets analyzed during the current study are available from the corresponding author on request.

COMPETING INTERESTS:

YP as President of Nutritional Strategies Inc. provides food, nutrition and regulatory affairs consulting services for numerous food and beverage companies and non-profit food associations and has collaborated with other researchers on NHANES analyses. JS is a Professor in the Department of Food Science and Nutrition, University of Minnesota and has current grants from Taiyo and Barilla in the area of dietary fiber, and also serves on the Scientific Advisory Boards for Tate and Lyle and Atkins Nutritionals and Sustainable Nutrition. YP and JS are active members of the Scientific Advisory Council for the Quality Carbohydrate Council in the United States. AP is a university student undergraduate intern at Nutritional Strategies Inc. and has no further declaration of interest.

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