HHS Public Access

Author manuscript

Food Qual Prefer. Author manuscript; available in PMC 2022 March 01.

Published in final edited form as:

Food Qual Prefer. 2021 March ; 88: . doi:10.1016/j.foodqual.2020.104076.

The addition of spices and herbs to vegetables in the National School Lunch Program increased vegetable intake at an urban, economically-underserved, and predominantly African-American high school

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Abstract

Vegetable intake is far below recommendations among African-American adolescents living in economically-underserved urban areas. While the National School Lunch Program (NSLP) helps overcome access barriers, vegetable intake remains challenging and novel interventions are required. A two-year, multi-phase, school-based intervention was conducted at an urban, economically-underserved, and predominantly African-American high school in Baltimore, Maryland to determine whether stakeholder-informed addition of spices and herbs to NSLP vegetables would increase intake. The stakeholder engagement phase included assessment of

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Declarations of interest: none

NSLP vegetable attitudes/preferences among 43 school stakeholders and subsequent student sensory testing. The second phase was conducted in the school cafeteria and consisted of eight weeks comparing student intake of typical vegetable recipes versus otherwise-identical recipes with spices and herbs. 4,570 student lunch plates were included in the vegetable intake comparison. Vegetable intake was measured by lunch tray plate waste. Willingness to try vegetables was assessed by the difference between plate waste and estimated mean vegetable served weight. Intake of typical vegetable recipes and vegetable recipes with spices and herbs was compared with student's t-test. Chi-square test was used to compare willingness to try vegetables. Total vegetable intake was 18.2% higher (8.22 grams per meal, $p<0.0001$) with spices and herbs than with typical recipes. There were no differences in trying vegetables with spices and herbs, although student-led advocacy was associated with increased trying vegetables with spices and herbs (78.8% with advocacy, 67.5% without advocacy, $p<0.0001$). The addition of spices and herbs to vegetables in the NSLP was feasible and associated with small increases in vegetable intake at an urban, economically-underserved, and predominantly African-American high school.

Keywords

spices; vegetables; economically-underserved; African-American; high school

INTRODUCTION

Diet quality among children and adolescents in the United States consistently falls below recommendations. Recent data from the National Health and Nutrition Examination Surveys (NHANES) revealed that the Healthy Eating Index score among school children nationwide was just 57.8 out of 100, reflecting major room for improvement.[1] The diet quality of low-income, African-American children and adolescents is particularly lacking.[2–4] Unhealthy dietary patterns in this demographic are reflected in a concerning combination of micronutrient deficiencies,[5,6] higher rates of obesity,[7] and increasing incidence of chronic disease.[8–11] A confluence of factors underlie these unhealthy dietary habits, but limited access to healthy foods at home and a lack of the economic means to purchase them often prove to be challenging for low-income children.[12,13]

While access to healthy foods is often limited at home, the National School Lunch Program (NSLP) of the United States Department of Agriculture (USDA) provides a means to help surmount some of the key barriers to healthy eating for low-income children and adolescents.[14] Changes to the NSLP in 2012–2013 that aligned school meals with the USDA Dietary Guidelines for Americans (DGA) for the first time included increased availability of fruits, vegetables, whole grains and reduction in the levels of sodium and trans fat in meals.[15] While these changes were clearly more nutritious,[16,17] they remain controversial due to both public perception that students find the healthier offerings unpalatable and some data suggesting decreases in school meal intake[18,19]. However, other studies have shown that NSLP intake has not decreased and may have increased in some settings after these changes.[20–22] Furthermore, low school meal intake is a longstanding problem, particularly with respect to vegetables. Data from the United States Centers for Disease Control and Prevention's Youth Risk Behavior Surveillance System reveal that just 2.1% of American

high school students meet federal recommendations for vegetable intake.[23] Irrespective of the recent mixed data, the historical issue of NSLP vegetable waste is a problem in need of novel interventions.

In recognition of this need, NSLP interventions that have demonstrated success in improving student vegetable intake include chef-enhanced meals,[24] role modeling, and awarding prizes for vegetable consumption.[25] While promising and warranting of further study, these programs focused on elementary and middle school students. High school students remain a particularly challenging demographic in which to inspire healthy dietary changes. Previous research conducted by D'Adamo, et al. with students at two urban, economically-underserved, and predominantly African-American high schools in Baltimore suggested that an experiential school-based nutrition education program focusing upon spices and herbs ("Spice MyPlate") improved diet quality and attitudes towards healthy eating more effectively than standard nutrition education.[26] While spices and herbs have been shown to offer numerous physiological benefits[27–32] and can be used to support the consumption of healthy, lower-sodium dietary patterns in adults,[33] the focus of Spice MyPlate was flavor enhancement through spices and herbs. Stakeholder engagement with high school students in Baltimore during the development of Spice MyPlate revealed that improved health was generally not a motivating goal for high school students and that flavor enhancement was far more likely to help overcome the undesirable taste barrier to consuming vegetables.

While flavor enhancement through spices and herbs was noted to increase attitudes towards eating vegetables in Spice MyPlate, participating students reported consuming only 0.5 cups of vegetables per day throughout the course of the study. This represented just 20% of the 2.5 cup-equivalent vegetable intake recommended by the DGA.[34] As such, the research team deemed increasing vegetable intake to be the priority area for subsequent dietary intervention among underserved Baltimore adolescents.

Inspired by the acceptability of spices and herbs and improvement in self-reported diet quality and attitudes towards eating vegetables demonstrated in Spice MyPlate, as well as recent data that demonstrated that spices and herbs can increase vegetable liking among high school students in both urban and rural settings,[35,36] the objective of the current study was to progress from school-based nutrition education to school-based dietary intervention by adding spices and herbs to the NSLP vegetables at an urban, economically-underserved, and predominantly African-American high school in Baltimore, Maryland that had not yet been exposed to dietary interventions of this nature. All Baltimore high school students are provided free access to vegetables through the NSLP, which the research team believed would help surmount some of the access and economic barriers to healthy eating noted among underserved population. The research team hypothesized that adding sensory-tested vegetable recipes containing spices and herbs to the NSLP would be feasible and provide modest increases in vegetable intake as compared to otherwise-identical "typical" vegetable recipes without spices and herbs. Furthermore, the research team expected that increases in vegetable intake with spices and herbs would be further increased by accompanying student-led advocacy for the new vegetable recipes.

MATERIALS AND METHODS

Study Overview and Ethical Approval

A two-phase, controlled intervention was conducted at a high school in Baltimore, Maryland during across two academic years. The intervention was approved by the Institutional Review Board of the University of Maryland School of Medicine and was registered on ClinicalTrials.gov (NCT02908854).

Participants and Setting

A wide variety of stakeholders at the urban high school (n=43) participated in this intervention. The stakeholder engagement that occurred in Phase One of the study, described in detail below, involved participation from school administrators (n=3), teachers (n=5), cafeteria staff (n=4), food services leadership (n=2), and students (n=29). Students in Phase One, from whom IRB-approved data were collected, provided both informed consent (signed by a parent or guardian) and assent (signed by the student). The comparison of vegetable intake between recipes flavored with spices and herbs and typical vegetable recipes in Phase Two of the study involved anonymous collection of student lunch trays for plate waste measurement of vegetable intake.

Further student engagement included formation of a Student Engagement Committee, named the "Lunch Bunch" by students, to evaluate the impact of student-led advocacy to eat vegetable recipes with spices and herbs. The Lunch Bunch student ambassadors were voluntarily recruited by school-wide announcements made by school administration and in-class announcements offered by teachers who had participated in the stakeholder engagement process. There were a total of nine Lunch Bunch student ambassadors, with two students each from Grades 9, 10, and 12 and three students in Grade 11. Students who participated in the Lunch Bunch also provided both informed consent and assent.

Stakeholder engagement and student recruitment for Phase One began in summer of the first academic year. Recruitment for the Lunch Bunch engagement began in winter of the second academic year. There was no recruitment or consent required for the vegetable intake comparison of Phase Two, as all students participating in the NSLP (100% of the student body was eligible for free meals) were eligible and provided their lunch trays for vegetable plate waste measurement anonymously.

There were 273 students enrolled at the high school at the onset of the intervention and the student body demographics were as follows: sex (57% female); race/ethnicity (Black or African-American 76%, Hispanic 10%, two or more races 10%, White 4%, Asian <1%); socioeconomic status (100% eligible for free school lunch).

Phase One: Stakeholder engagement and vegetable recipe sensory-testing

The stakeholder engagement process began with a series of meetings between the research team, school administration, and food services personnel to discuss the nutritional needs of the student body and the feasibility of potential intervention approaches to address these needs. After it was determined that a school-based intervention centered around the addition

of spices and herbs to the vegetables in the NSLP would be feasible, students were invited by school administration, teachers, and cafeteria staff to participate in an after-school program that included education on taste perception, exposure to spices and herbs, vegetable flavor enhancement with spices and herbs, and sensory-testing of vegetable recipes flavored with spices and herbs.

The after-school student program was led by two health educators and a professional chef that were experienced in leading experiential nutrition education for Baltimore high school students.[26,37] The program consisted of 10 sessions that were each one and a half hours in length. In addition to nutrition and sensory education, 2–4 vegetable recipes were sensory-tested and rated during each session for flavor, appearance, texture, and odor. The sensory tests included typical vegetable recipes, which included only NSLP-compliant amounts of salt and oil that were representative of the vegetables served in the school cafeteria and others across the country, to determine if any were superior to the new recipes flavored with spices and herbs. Recipes were rated on a 1 to 5 Likert scale on each sensory dimension as well as an overall "winner" rating provided by the students as reported by Parker et al.[36] The recipes flavored with spices and herbs that received the highest winner ratings were selected for the vegetable intake comparison in Phase Two versus the typical vegetable recipes.

The spices and herbs included in the vegetable recipes for each vegetable in the intake comparison in Phase Two are provided in Table 1. In brief, the spices and herbs that most consistently appeared in the student sensory-tested vegetable intervention recipes included onion powder, garlic powder, cayenne pepper, black pepper, and dill weed.

Phase Two: Comparison of vegetable intake with and without spices and herbs

Each student was provided with a serving of vegetables at lunch every day. Vegetables were not labeled and only one vegetable recipe was served at lunch each day. The absence of recipe names and the lack of daily choice of different vegetables facilitated direct comparison between vegetable intake with typical recipes and vegetable intake with recipes containing spices and herbs. While several methods of assessing student vegetable intake were considered, weighed plate waste was selected for the primary outcome of the study as it has been used in many previous cafeteria studies[24,38–40]. Weighing food seems to be associated with the least error and is therefore referred to as the "gold standard" of measuring food intake in this setting. Two OHAUS Gold Series SPJ601 scales were utilized to weigh the vegetable plate waste.

Vegetables were served in a separate container on each student's lunch tray to allow for precise weighing of the returned vegetables that the student had not consumed (plate waste). Separate vegetable containers provided protection against potential difficulties of manual separation of vegetables from other foods served for lunch. This method enabled the research team to avoid imprecise manual separation of the vegetables prior to weighing. Vegetables were served in this manner from the beginning of the academic year to minimize the potential for confounding from a novel vegetable serving vehicle.

In consideration of variability in weight from serving to serving that can occur in cafeteria settings, the daily served weight for each vegetable was estimated by calculating the mean

weight of 10 separate servings that were provided by cafeteria staff to the research team on each day of the intervention. Evaporation was also accounted for in the calculation of the estimated served weight by waiting several minutes prior to weighing the vegetable samples to simulate the length of time from the point at which a student was served vegetables in the lunch line to when the student would arrive at a table, sit down, and consume them.

To accommodate the high volume of students returning lunch trays for vegetable collection and weighing at the lunch period conclusion, between four to seven research staff were on site at the cafeteria on each day of the intervention. Students returned their lunch trays at trash can stations in the cafeteria (as they normally did prior to the intervention) to research staff, which ensured collection of 100% of student lunch trays since there was nowhere else in the cafeteria to return the trays. Research staff then separated and delivered the vegetable containers to two research staff who weighed the vegetables. Potential vegetable container exclusions were flagged by the research staff per the following criteria that would result in inaccurate weighing: 1.) unconsumed vegetables removed from the vegetable container and mixed with another portion of the plate, 2.) unconsumed non-vegetable food items added to the vegetable container, and 3.) any other reason (missing vegetable container, uncooperative student, etc.). The description of each potential vegetable container exclusion was subsequently confirmed or rejected by the principal investigator prior to analysis.

The feasibility of the data collection process was established during a trial run conducted in September. Vegetable intake was then formally assessed in this manner during two separate four-week periods in November-December and April-May. During each four-week period, the typical vegetable recipes were served and collected for weighing for two consecutive weeks, followed by the vegetable recipes with spices and herbs being served and collected for weighing for another two consecutive weeks. The weekly rotation of vegetables served was consistent (e.g. broccoli on Mondays, carrots on Tuesdays, etc.) within each of the two four-week intake assessment periods conducted in the Fall and Spring. The two-week consecutive duration for both the typical and spices and herbs vegetable recipes was incorporated within each four-week assessment period to account for potential confounding of the student intake or trying of vegetables due to novelty of the appearance of the new recipes as well as the research team's presence in the cafeteria. The trial data collection period also provided previous exposure to the research team's presence prior to the intervention. Vegetable intake was assessed during both of the two lunch periods during each school day. This data collection schedule resulted in approximately forty lunch periods in which student vegetable intake was assessed in the Fall and another forty lunch periods in which student vegetable intake was assessed in the Spring.

The "usual condition" of typical steamed vegetable recipes utilized vegetable oil and salt for flavoring and were in accordance with what had been previously offered in the cafeteria as well as all NSLP guidelines. The "intervention condition" of vegetable recipes flavored with spices and herbs utilized the same amounts of vegetable oil and salt as the typical vegetable recipes and were also in accordance with all NSLP guidelines.

The vegetables assessed in the intake comparison between typical recipes versus spices and herbs recipes were as follows: broccoli, carrots, California medley (broccoli, carrots,

cauliflower), peas, black beans and corn, and green beans. The vegetables were frozen, briefly steamed, and oil and salt (usual condition) or oil, salt, and spices and herbs (intervention condition) were added after steaming. To capture another vehicle of vegetable consumption, intake of raw carrots was also compared between typical dip and dip with spices and herbs.

Three vegetables were served in both semesters: broccoli, carrots, and California medley. The peas and black beans and corn recipes were offered only during the Fall semester, due to preparation inconsistencies that confounded the comparison. The black beans and corn contained more liquid on some days (thereby increasing served weight) and less on other days (thereby decreasing served weight), which was also noted by students and the research staff to decrease their appeal irrespective of the content of spices and herbs. The peas recipe with spices and herbs did not mix as well as the other recipes, as the spices and herbs were poorly dispersed across the large batches that were served. These vegetables were replaced with green beans and raw carrots, which were offered only during the Spring semester.

A secondary outcome was the effect of student-led advocacy for consuming vegetables with spices and herbs. As noted previously, this group of students was named the "Lunch Bunch" and the engagement involved six after-school sessions that were one hour in duration each. Students from each of grades 9–12 were included in this engagement. The goal of the Lunch Bunch was to create and implement a student-led engagement process to encourage fellow students to consume the new vegetable recipes with spices and herbs. After discussing and considering a variety of potential engagement vehicles, the Lunch Bunch chose to focus their efforts on offering cafeteria posters and school-wide daily announcements over the school's intercom system. By design, the advocacy was brief and student-led; requiring minimal time and resource investment to foster reproducibility in other school settings. The Lunch Bunch provided advocacy only during the second semester of the intervention to allow for intake comparison to the "naïve" first semester of the intervention that did not include student-led engagement.

Statistical Methods

Descriptive statistics were computed to characterize the sample of students participating in the stakeholder engagement. Mean daily student vegetable intake (in grams) was calculated as the difference between the estimated serving weight and the weight of vegetable plate waste that each student returned. Willingness to try the served vegetables was dichotomously assessed as either "tried vegetables - yes" (lower vegetable plate waste weight than the estimated serving weight) or "tried vegetables - no" (equal or higher vegetable plate waste weight than the estimated serving weight).

Comparison of student vegetable intake between typical vegetable recipes and recipes with spices and herbs was performed using student's t-test. Pooled and Satterthwaite variance methods were assessed and no meaningful differences were determined. Thus, pooled (equal) variance assumptions were used throughout these analyses. The comparison of trying the typical vegetable recipes versus vegetables with spices and herbs was conducted using chi-square test.

All statistical analyses were performed individually for each semester and then assessed for heterogeneity via a generalized linear regression model with a product term. No significant heterogeneity was determined and analyses pooling data across semesters were conducted.

The primary analysis compared total student intake of typical vegetable recipes to total student intake of vegetable recipes with spices and herbs across all vegetables tested in both semesters. Secondary analyses were conducted stratified by the type of vegetable served and the semester.

As noted previously, three vegetables were served in both semesters: broccoli, carrots, and California medley. This allowed for examination of semester-specific estimates of the potential for synergistic effects of student-led advocacy on vegetable intake and trying among the vegetable recipes that mixed consistently and were served in both semesters. Regression models of intake and willingness to try vegetables that were offered in both semesters that included semester x spices and herbs interaction terms were constructed to estimate the effect of student-led advocacy. However, regression modeling only provided an estimate of the true effect of the student-led advocacy as repeated exposure to spices and herbs may have also impacted changes in vegetable intake in the Spring semester in which the advocacy was offered.

All analyses were performed in SAS version 9.4[41] utilizing TS Level 1M4 analytic procedures. Data management and visualization was conducted in SAS Enterprise Guide v7.13.

RESULTS

A total of 29 students participated in the sensory testing process of the student engagement to inform and support the vegetable intervention. The characteristics of the student engagement sample were as follows: sex (female = 55%, male = 45%), race/ethnicity (Black or African-American = 94%, White = 3%, two or more ethnicities = 3%), grade (9^{th} = 69%, 10^{th} = 3%, 11^{th} = 14%, 12^{th} = 14%). Detailed results of the student sensory testing of vegetable recipes with spices and herbs are reported elsewhere[36] with the spices and herbs featured in the most liked recipes used in this intervention are provided in Table 1.

The results of the student vegetable intake comparison between typical recipes and recipes with spices and herbs are provided overall and for each vegetable and semester in Table 2. In brief, a total of 4,602 plates were collected from students and 4,570 of these plates (typical = 2,410 & spices and herbs = 2,160) were included in the vegetable intake comparison analysis. There were 32 plates removed from the analysis (0.7% of sample) due to identification as exclusions by the research staff weighing the vegetables with confirmation from the principal investigator. The most common reason for plate exclusion was the presence of unconsumed vegetables that had been removed from the vegetable container and mixed with another portion of the plate.

Vegetable intake was 18.2% higher with spices and herbs than typical preparations (44.8 grams typical, 53.0 grams spices and herbs, $p < 0.0001$). Five vegetables tested had higher intake with spices and herbs (steamed carrots, broccoli, California medley, green beans, raw

carrots) and two vegetables tested had higher intake with typical recipes (peas, black beans and corn).

Analysis of vegetable intake limited to recipes in which preparation was consistent (steamed carrots, broccoli, California medley, green beans, raw carrots), revealed greater increases in vegetable intake with spices and herbs as compared to typical recipes (34.2%, 15.0 grams, $p<0.0001$).

The interaction on vegetable intake between recipes with spices and herbs and student-led advocacy for consuming vegetables with spices and herbs was also assessed. 2,397 plates were collected in the naïve semester and 2,197 plates were collected in the semester with student-led advocacy. Total vegetable intake was 15.4% higher than typical recipes with spices and herbs without student-led advocacy and 27.2% higher than typical recipes with the student-led advocacy, although the advocacy x spices and herbs interaction term in the linear regression model was not statistically-significant ($p = 0.08$).

The results of the vegetable trying comparison between typical recipes and those with spices and herbs are presented overall and for each vegetable in Table 3. Overall, there was no difference in vegetable trying (typical = 76.5%, spices and herbs = 74.2%, $p = 0.07$). However, more students tried typical vegetables in the semester without student-led advocacy (typical = 84.2%, spices and herbs = 69.9%, $p<0.0001$) and more students tried vegetables with spices and herbs in the semester with student-led advocacy (typical = 67.5%, spices and herbs = 78.8%, $p<0.0001$).

DISCUSSION

The addition of spices and herbs to vegetables in the NSLP was feasible and associated with modest increases in vegetable intake at an urban, predominantly African-American, and exclusively low-income high school in Baltimore. The magnitude of the impact of spices and herbs on total vegetable intake (18.2% increase, 8.22 grams, $p<0.0001$) was dampened by heterogenous effects that varied greatly by specific vegetable. Adding spices and herbs was associated with increases in intake of most of the vegetables that were tested (steamed carrots, broccoli, California medley, green beans, raw carrots), but also decreases in some others (peas, black beans and corn). Similarly, more students tried five of the seven vegetables tested with spices and herbs (steamed carrots, broccoli, California medley, green beans, raw carrots), but students were also much more likely to try the other two vegetables with typical preparation (peas, black beans and corn). The importance of willingness to try the vegetables was reflected by the consistent relationship of trying with intake of both typical recipes and recipes with spices and herbs across all seven vegetables studied.

Students at this school had strongly unfavorable attitudes towards and low intake of school lunch vegetables, as expressed throughout the stakeholder engagement phase[36] and the very low intake of typical vegetable recipes throughout the study (mean of 44.8 grams). Poor attitudes toward vegetables and unfamiliar foods likely precluded many students from trying the new vegetables with spices and herbs, especially prior to the Lunch Bunch student-led advocacy. The students' generally poor attitudes toward eating vegetables is reflective of the

challenge faced at many underserved and predominantly African-American urban schools across the United States.[42,43]

With the challenge of school lunch vegetable acceptance and intake among this demographic in mind, the research team was encouraged by the increase in vegetable trying and intake associated with the student-led advocacy for the vegetable recipes with spices and herbs provided by the Lunch Bunch. The student-led advocacy required minimal school staff time and financial resources as students led the creation of the basic signage posted throughout the school and the announcements over the school intercom. The researchers hypothesize that the voluntary, as opposed to mandatory, nature of the Lunch Bunch recruiting fostered genuine enthusiasm among these students for helping their fellow students improve their diet quality. While the increase in total vegetable intake with the addition of spices and herbs compared to total intake of typical vegetables was greater with student-led advocacy, the spices and herbs by student-led advocacy interaction term in regression modeling was not statistically-significant ($p=0.08$). It is also possible that some portion of the increase in willingness to try and intake of vegetables noted with the student-led advocacy may have been due to repeated exposure to spices and herbs carrying over from the first semester, which may influence vegetable intake among young people.[44,45] This suggests that while student-led advocacy may have a positive effect supporting the introduction of vegetable recipes with spices and herbs, the increase in total vegetable intake in this study appeared to be due more to the addition of spices and herbs itself than the student-led advocacy. However, future studies would need another phase of the intervention consisting solely of student advocacy to confirm this hypothesis.

The authors believe that the clinical relevance of adding spices and herbs to NSLP vegetables is that it is not a standalone solution to the problem of low vegetable intake among underserved African-American adolescents, but rather, another useful tool that may feasibly complement other previous school-based interventions that were successful. Interventions that have demonstrated success in increasing vegetable intake that could be offered in combination with the addition of spices and herbs in similar school settings include salad bars,[46] experiential nutrition education,[26] involving professional chefs[24] at school, providing rewards for vegetable intake,[25] and other student-informed social determinants of vegetable intake such as peer-to-peer influence.[47] The effect sizes of these interventions were generally modest in isolation and many students still fell short of the daily 2.5 cup-equivalent of vegetable intake recommended by the DGA. However, the authors hypothesize that there could potentially be synergistic improvement in vegetable intake if offered in multimodal combination as different interventional vehicles are likely to resonate with different students even within the same setting. While the increases in intake were more notable for fruits than vegetables, a multimodal approach including attractive names and serving modifications has been shown to increase fruit and vegetable intake.[48] Adding spices and herbs to served NSLP vegetables could feasibly be added as another component to such a multimodal approach.

There were a number of notable strengths of this study. With over 4,500 school lunch trays collected from an entire student body over the course of four months spanning both semesters of an academic year, this was the one of the largest, lengthiest, and most inclusive

assessments of vegetable intake conducted at a high school to date. The exceptionally large sample of students and the extended duration of the study provided ample statistical power to detect differences between typical recipes and recipes flavored with spices and herbs with respect to total vegetable intake, intake of specific vegetables, and vegetable intake with and without student-led advocacy. The fact that the entire student body was eligible for the NSLP, and thus the study, minimized the potential for selection bias and enhances the generalizability of the findings.

The willingness of the school administration to implement school-wide changes to the NSLP vegetable recipes and the approval from the Institutional Review Board to study the effects on vegetable intake among the entire study body was greatly facilitated by the extensive stakeholder engagement process that preceded the school lunch intervention. Stakeholders that were engaged included school administration, teachers, cafeteria staff, food services personnel, and students to attain the "buy in" and strategic partnership necessary to successfully implement and evaluate a school-wide intervention of this nature. Along these lines, the sensory-testing that was conducted during the stakeholder engagement process also helped the research team determine flavors and other sensory properties that were acceptable to the students[36] to help optimize the success of the spices and herbs combinations that were ultimately selected for the intake comparison versus typical vegetable recipes.

The intervention was designed to be reproducible in other school settings in several ways. In addition to the affordability, broad accessibility, and minimal kitchen and cafeteria disruption associated with the addition of the selected spices and herbs to school lunch vegetables, all recipes were compliant with NSLP requirements and could be offered in any high school cafeteria across the United States. Furthermore, the addition of spices and herbs was the only difference between the typical vegetable recipes to which they were compared. There were no differences in salt, fat, sugar, or total caloric content between the vegetable recipes that would have introduced confounding to the comparison. This feature of the recipes helped the research team isolate the specific effects of adding spices and herbs on vegetable intake.

Several other measures were incorporated to reduce potential confounding in the comparison between the typical vegetables and vegetable recipes with spices and herbs. The research team was mindful of the potential for confounding introduced by novelty of new recipes as well as the presence of the research team in the cafeteria. The potential for novelty bias due to research team presence in the cafeteria during lunch was reduced by the research team's presence during the week of trial runs of the plate waste data collection process that preceded the actual intervention. The novelty of the vegetable recipes flavored with spices and herbs was also addressed by the minimum two-week period that intake of the various vegetable recipes with spices and herbs was measured throughout each usual condition and intervention condition for which data were collected in the study. Finally, potential confounding of novelty that might have been introduced by separate containers of vegetables on each plate was minimized by the school cafeteria's permission to serve vegetables in this manner from the very beginning of the academic year of the intervention far in advance of any of the plate waste data collection in this study.

The accuracy of the vegetable intake assessment was of paramount importance to the comparisons in this study. Numerous safeguards were taken to ensure the rigor and accuracy of student vegetable intake measurement. Weighed plate waste is a relatively accurate assessment for determining dietary intake in cafeteria settings and serving vegetables in separate containers on each plate improved precision since there was no manual separation of vegetables from plates required. As another measure to foster vegetable intake measurement precision, estimating the mean served weight from multiple samples every day helped account for variability in scooped serving size that can occur in cafeteria settings. The research team also allowed several minutes prior to weighing each of the vegetable servings to account for evaporation that would occur from the time vegetables were served to the time that the student would consume them. Stakeholder engagement revealed that vegetables were rarely consumed first, and it was important to account for weight that would be typically lost from evaporation by the time the vegetables were consumed. Collectively, these strategies helped reduce measurement error that can occur in school cafeterias.

There were also several important limitations of this study. Randomization of students to receive either typical vegetable recipes or vegetable recipes with spices and herbs and adjustment for potential confounders in regression modeling (age, gender, race/ethnicity, etc.) was deemed infeasible during the stakeholder engagement phase as this would have required informed consent and student assent from the entire student body. This limitation was mitigated by the nature of the research question, which was oriented less towards the efficacy of the intervention under ideal conditions and more towards assessment of the feasibility and effectiveness of this intervention in the "real world" circumstances of a high school cafeteria. Segregating the students based on the vegetables to which they were randomized would not have reflected the typical conditions in a high school kitchen and cafeteria.

A related limitation was that the real world setting of the high school kitchen and cafeteria led to some variability in the serving and preparation of the vegetables under study. While the mean of ten served vegetable samples was utilized on each day of data collection to estimate mean daily served weight in the willingness to try vegetables measurement, this assessment has not been validated in previous studies and there still may have been residual serving-to-serving variation in weight. Despite many efforts to ensure consistency in the preparation of vegetables and the subsequent assessment of student vegetable intake, it was noted that some of the vegetables occasionally varied in consistency from day to day across each of the two-week periods during which student intake was assessed. The black beans and corn and the peas, in particular, were noted to have more preparation inconsistencies than the other vegetables. Both of these recipes were better suited to the smaller batches that were initially sensory-tested by students in the stakeholder engagement phase than when brought to scale for the entire school. In order to rectify this limitation, vegetable recipes with spices and herbs that did not scale well to the much larger volumes required to serve the entire school were replaced with new vegetables commonly served at school (green beans and raw carrots) in the second semester of the intervention.

Another limitation related to feasibility of measuring vegetable consumption among an entire student body in a school cafeteria setting was the challenge in obtaining liking data to

accompany the vegetable consumption data. The research team considered distributing a liking survey to each student along with the school lunch meal to be subsequently collected along with the finished lunch tray prior to measuring vegetable plate waste, but the feasibility of this study design feature was deemed to be prohibitively challenging in the busy cafeteria setting. Furthermore, school stakeholders suggested that both the student engagement and completion rate of such a liking survey distributed with each meal would be low and subjected to bias when distributed to all students. Thus, in the absence of data directly evaluating the association between increased vegetable consumption and increased liking, such an association is left to hypothesis until confirmation in future studies.

While the results of this intervention adding spices and herbs to the NSLP vegetables at an urban, underserved, and predominantly African-American high school in Baltimore are encouraging, the modest increases suggest the ongoing need for multidimensional interventions. The findings may not be generalizable to other student demographics in which taste preferences, food access, and previous exposure may differ and further studies appear warranted to assess the effectiveness of this intervention in other school settings.

CONCLUSIONS

While multidimensional efforts are necessary to optimize NSLP vegetable intake at urban, underserved, and predominantly African-American high schools, the addition of spices and herbs to school lunch vegetables is feasible, well-accepted by students, and may provide small increases in student vegetable intake. Student-led advocacy might also help encourage fellow students to try new vegetable recipes and potentially further increase vegetable intake. While replication is necessary in future studies, the minimal investment of financial and school staff resources for both the addition of spices and herbs and accompanying student-led advocacy would allow for reproducibility in other underserved high school settings.

ACKNOWLEDGMENTS

The authors express their sincere gratitude to the students, parents and guardians, school administration, teachers, and cafeteria stuff at the high school in Baltimore in which the intervention was conducted for their enthusiastic partnership in this research. We would also like to thank the McCormick Science Institute for offering the services of their research chefs and sensory scientists in helping develop and prepare the vegetable recipes that were sensory tested by the students. Lastly, the authors thank Ruth Abate, Donna Aubinoe, Christina Brockett, Alica Diehl, Deborah Taber, Katie Irwin, students and administrative leadership at Maryland University of Integrative Health, and the community programs staff at the Institute for Integrative Health for their passionate efforts partnering with school staff and students in ensuring successful implementation of all phases of this study.

FUNDING

This work was supported by the McCormick Science Institute and the National Institutes of Health [grant number T35 DK095737].

Abbreviations:

NSLP	National School Lunch Program
USDA	United States Department of Agriculture
DGA	Dietary Guidelines for Americans

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HIGHLIGHTS

1. Adding spices and herbs to vegetables was feasible at a predominantly African-American high school
2. There were modest increases in vegetable intake when spices and herbs were added
3. Willingness to try vegetables was not impacted by adding spices and herbs

Table 1:

Spices and herbs contained in the vegetable recipes of the National School Lunch Program intervention at a high school in Baltimore, Maryland

Vegetable	Spices and Herbs
Broccoli	Dill weed, garlic powder, onion powder, black pepper
Carrots	Cayenne pepper, ginger, garlic powder, onion powder
California Medley (Broccoli, Carrots, Cauliflower)	Dill weed, garlic powder, onion powder, black pepper
Peas	Coriander, garlic powder, onion powder, black pepper
Black Beans & Corn	Cayenne pepper, cumin, oregano, garlic powder, onion powder
Green Beans	Parsley, garlic powder, onion powder, black pepper
Raw Carrots with Dip	Cayenne pepper, dill seed, dill weed, parsley, garlic powder, onion powder, black pepper

Table 2:

Student National School Lunch Program vegetable intake with typical recipes versus recipes with spices and herbs at a high school in Baltimore, Maryland

Vegetable	Semester	N*	Typical Daily Vegetable Intake Mean (Standard Deviation) grams	Spices and Herbs Daily Vegetable Intake Mean (Standard Deviation) grams	Percent Change	p-value**
Total	Both	4570***	44.8 (38.8)	53.0 (45.6)	18.2%	<.0001
	Fall	2397	46.2 (36.6)	53.3 (49.0)	15.5%	<.0001
	Spring	2173	43.1 (41.4)	52.4 (41.7)	21.8%	<.0001
Broccoli	Both	986	54.1 (40.0)	69.7 (44.8)	28.8%	<.0001
	Fall	606	51.0 (35.7)	70.9 (48.5)	39.0%	<.0001
	Spring	380	58.4 (44.2)	68.0 (35.4)	16.5%	0.02
Carrots	Both	923	33.7 (29.5)	49.6 (37.1)	47.0%	<.0001
	Fall	478	30.6 (29.8)	65.8 (36.6)	115%	<.0001
	Spring	445	38.6 (28.9)	36.3 (31.8)	(6.34%)	0.4
California Medley (Broccoli, Carrots, Cauliflower)	Both	960	49.6 (41.1)	74.6 (46.2)	50.5%	<.0001
	Fall	505	51.3 (40.5)	64.4 (49.3)	25.3%	0.001
	Spring	455	47.6 (41.7)	86.7 (38.8)	81.7%	<.0001
Peas	Fall	358	35.2 (38.6)	15.6 (30.6)	(55.9%)	<.0001
Black Beans & Corn	Fall	450	61.8 (29.2)	28.1 (46.8)	(54.7%)	<.0001
Green Beans	Spring	390	38.6 (37.7)	45.1 (33.2)	17.0%	0.07
Raw Carrots with Dip	Spring	503	28.9 (33.4)	38.6 (42.8)	32.5%	0.02

*Number of student lunch trays included in vegetable plate waste analysis

**P-values calculated with student's t-test

***Total typical vegetable plates collected across both semesters (n=2,410); total spices & herbs vegetable plates collected across both semesters (n=2,160)

Table 3:

Percentage of students who tried any of the National School Lunch Program vegetables with typical recipes versus recipes with spices and herbs at a high school in Baltimore, Maryland

Vegetable	Semester	N*	Percentage of Students That Tried Typical Vegetables**	Percentage of Students That Tried Spices & Herbs Vegetables**	p-value***
Total	Both	4570	76.5	74.2	0.07
	Fall	2397	84.2	69.9	<.0001
	Spring	2173	67.5	78.8	<.0001
Broccoli	Both	986	84.9	90.7	0.005
	Fall	606	90.6	90.2	0.9
	Spring	380	77.7	91.7	0.0003
Carrots	Both	923	74.6	80.2	0.05
	Fall	478	78.2	89.2	0.001
	Spring	445	69.2	72.7	0.4
California Medley (Broccoli, Carrots, Cauliflower)	Both	960	76.5	85.0	0.0008
	Fall	505	81.7	76.1	0.12
	Spring	455	71.3	95.7	<.0001
Peas	Fall	358	70.0	34.2	<.0001
Black Beans & Corn	Fall	450	97.8	37.2	<.0001
Green Beans	Spring	390	68.0	82.3	0.001
Raw Carrots with Dip	Spring	503	51.2	61.7	0.02

*Number of student lunch trays included in vegetable plate waste analysis

**Percentage of students estimated to have tried the vegetables served at lunch, as categorized by returned vegetable plate waste less than the mean daily served weight

***P-values calculated with chi-square test