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Increasing flavor variety with herbs and spices improves relative vegetable intake in children who are propylthiouracil (PROP) tasters relative to nontasters

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ABSTRACT

American children do not meet the recommended daily servings of vegetables, and previous research suggests children who can taste the bitterness of 6-n-propylthiouracil (PROP) are more likely to have low vegetable intake. This study tested the hypothesis that adding multiple herb and spice blends to vegetables to increase flavor variety within a meal would increase vegetable intake in 3–5 year-old children. Children attended two laboratory visits and consumed two test meals of common foods: macaroni and cheese, applesauce, carrots, milk, and water. On one visit, the meal included three servings of carrots with different herb and spice blends (*Variety* condition). On the other visit, all three servings of carrots were seasoned with the same herb and spice blend (*No Variety* condition). Overall, children consumed similar amounts of carrots by condition (36.5 ± 40.5 g versus 35.9 ± 43.8 g at the *Variety* and *No Variety* conditions, respectively); however, this relationship was moderated by PROP status. Children who tasted PROP as bitter (tasters) consumed a greater proportion of carrots during the *Variety* condition relative to nontasters ($p = 0.03$). These findings suggest that children who taste PROP as bitter may be more receptive than nontasters to manipulations that increase flavor-variety of vegetables using herbs and spices.

1. Introduction

In the United States, children consume 80% fewer vegetables than recommended [1]. This is a public health concern because adequate consumption of vegetables has been associated with lower risk for developing diseases like type 2 diabetes, cancer, and coronary heart disease [2]. Most vegetables are also low in energy and may displace more energy dense foods from the diet, which may therefore help prevent excessive weight gain [3,4]. Accordingly, novel and effective strategies to bolster vegetable intake in children are warranted. This study investigated the use of flavor variety, created by adding herbs and spices, to increase children's vegetable intake within a meal.

Offering a variety of flavors has been shown to increase overall food intake [5–9], and has been used to promote vegetable intake in adults at a meal [8] and vegetable intake in children at a snack [9]. Variety can reduce the effects of sensory specific satiety, defined as the decrease in reported liking that occurs when a single food is consumed to satiation, relative to a noneaten food [10,11]. Having multiple food and flavor options also increases the likelihood that at least one will be well liked, and potentially consumed. Herbs and spices are a good candidate for increasing sensory variety in vegetables because they offer a wide range of flavors without contributing additional energy. As an added benefit, increasing herb and spice consumption among children may also offer additional health benefits as they are rich in polyphenols and other antioxidants that have been associated with prevention of diseases like cancer, type 2 diabetes, and neurodegenerative diseases [12,13].

While young children may be unfamiliar with the flavor of many herbs and spices, there is evidence that children can learn to accept new flavors with repeated exposure [14–16]. Spices have been tested as a method to increase vegetable intake among toddlers using flavor-flavor learning (a form of Pavlovian conditioning whereby familiar liked flavors are paired with unfamiliar, less well-liked flavors), although the impact of spices was not greater than that of repeated exposure [17]. In

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addition, the incorporation of herbs and spices into a yogurt-based dip has been shown to increase vegetable intake among 3–5 year-olds [18]. Therefore, there is precedent for using herbs and spices to improve dietary intake in children, although more investigation is needed.

Individual differences in flavor perception may also influence children's acceptance of both vegetables and seasonings like herbs and spices. The ability to perceive low concentrations of 6-n-propylthiouracil (PROP), a bitter taste compound that activates receptors encoded by the *TAS2R28* gene [19], has been associated with differences in acceptance and intake of vegetables in children. Specifically, some studies show that PROP tasters are less accepting [20,21] and consume fewer bitter green vegetables than PROP nontasters [22–24], although not all studies confirm these results [25,26]. In adults, PROP tasters have also been shown to rate herbs and spices as stronger, spicier, and more pungent than nontasters [27], but this has not been tested in children.

The goal of this study was to determine whether introducing a variety of flavors with the use of herbs and spices could increase children's consumption of a single vegetable served in the context of a multi-item meal. We hypothesized that children would consume more carrots when a variety of seasoned carrots were served with a meal compared to when only one version of seasoned carrots was available. A second objective was to identify potential moderators of the intervention's effects. We assessed PROP status as a proxy for overall oral responsiveness [28,29], hypothesizing that PROP tasters would have heightened sensitivity to the orosensory properties of herbs and spices and, therefore might be less receptive to blends that included more pungent varieties. Finally, a trained panel of adults was used to systematically quantify the flavor profiles of the various herb and spice blends to enhance our interpretation of the results.

2. Methods

2.1. Study design

Children attended two, 2-hour laboratory visits, spaced about 1 week apart. Two test meal conditions were served in a counterbalanced order in a within-subject crossover design. Meals were offered at either lunch (11 am–2 pm) or dinner time (4:30–7 pm), depending on family availability, but visit times were constant for a given participant. Anthropometrics and PROP status were assessed on the first visit, and food acceptability tests were conducted on both visits. During each visit, parents were asked to fill out questionnaires in an adjacent room where they could watch the test procedures through a one-way mirror. In a subsequent portion of the study, a panel of adults evaluated the herb and spice blends using standard descriptive analysis methods to provide a quantitative flavor profile of the blends. All study procedures with the children were approved by the Institutional Review Board at the Pennsylvania State University. Parents provided written consent for their child's participation and children gave verbal assent. The adult panel data were exempted from Institutional Review Board review by professional staff in the Penn State University Office of Research Protections (ORP) under the wholesome foods/approved food additives exemption in 45 CFR 46.101(b)(6).

2.2. Participants

Seventy-nine child/parent dyads were screened over the phone based on responses to flyers and advertisements posted on local parent/family websites. Fifteen children were excluded at screening for not meeting eligibility criteria (i.e., parents reported they would not eat the test meal foods, would not be comfortable in a room without a parent, were taking medication that can affect taste or appetite, etc.) and 16 could not participate due to scheduling conflicts. Four additional participants were excluded after their first visit because the child refused to participate and/or would not taste any of the carrots. The final sample included forty-four children (n = 44) who completed both test meal visits between February 2015 and November 2016. Children were aged 3–5 years old, with the exception of one child tested shortly after his 6th birthday due to a need to reschedule his visit. Participant characteristics are summarized in Table 1.

Table 1
Children's anthropometric measurements and demographic information.

Child Characteristics	
Sex	% (*N*)
Male	56.8 (25)
Female	43.2 (19)
Race/ethnicity	
White	93.2 (41)
Hispanic or Latinx	2.3 (1)
Asian	2.3 (1)
Mixed Race	2.3 (1)
Weight classification	
Non-overweight (BMI %ile 0-85th)	79.5 (35)
Overweight (BMI %ile > 85th)	20.5 (9)
PROP status	
Nontaster	20.5 (9)
Taster	79.5 (35)
Age	Mean ± SD
Child age in months	54.2 ± 8.2
Body Mass Index	
BMI percentile	57.0 ± 29.2
BMI z-score	0.23 ± 0.98

2.3. Test meal procedures and presentation

On each of the two visits, children consumed an ad libitum multi-item test meal consisting of macaroni and cheese (175 g), unsweetened applesauce (115 g), 2% milk (240 g), water (465 g), and three servings of microwave-steamed crinkle cut carrots (40 g each). As part of a pre-meal liking assessment, children tasted bite-sized portions (~5 g each) of the macaroni, applesauce, carrots, and milk, served in a fixed order in 2 oz. plastic cups. Children rated the foods on a 5-point smiley face scale ranging from “super bad” to “super good”. Between the liking assessment and the meal, children rated perceived fullness using a 3-point silhouette scale and this was treated as a covariate in our analyses. For the test meal, foods were served in plain white bowls, while beverages were served in child-friendly reusable plastic “juice boxes” to avoid spills. In the *Variety* condition, each serving of carrots was seasoned with one of three spice blends (Cinnamon-Nutmeg-Ginger, Cardamom-Cumin-Allspice, and Garlic-Black Pepper-Oregano). In the *No Variety* condition, carrots were all seasoned with the cinnamon blend, but were served in separate bowls to be consistent in appearance with the *Variety* condition. Children were given 30 min and told they could eat as much as they wanted while a research assistant read a non-food related story as a neutral distraction. No additional servings of food were provided. Following the meal, children rated fullness again, and then completed an identical post-liking assessment with the four meal items. To minimize testing fatigue, the pre- and post-meal liking assessments included only carrots seasoned with the cinnamon blend.

2.4. Measures of vegetable liking and preference

On visit one only, children were given an additional liking assessment prior to the one with the test meal items. This liking assessment consisted of carrots seasoned with each of the 3 blends used in the Variety meal (1 carrot slice of each), a salted control carrot for comparison, and broccoli samples seasoned with the 3 spice blends (1 small floret of each), all served in 2 oz. plastic cups with a lid. Broccoli was included to gather pilot data about children's liking of spice blends on a green vegetable to see if liking results would generalize across vegetable type.