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Vegetable variety: an effective strategy to increase vegetable intake in adults

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Abstract

Effective strategies are needed to increase vegetable intake in accordance with health recommendations. Previous research has shown that increasing the variety of foods leads to increased consumption, yet this strategy has not been investigated for promoting vegetable intake. This cross-over study tested whether filling half the plate with a variety of vegetables influences vegetable consumption and meal energy intake. Once a week for 4 weeks, a meal of pasta and cooked vegetables was consumed ad libitum by 66 adults (34 women; 32 men). The meals were varied in the type of vegetables offered; at three meals 600 g of a single vegetable was served (broccoli, carrots, or snap peas) and at one meal 200 g of each of the three vegetables was served side by side. The experiment was conducted in 2008 and 2009 and data were analyzed using a mixed linear model with repeated measures. The results showed that serving a variety of vegetables increased vegetable intake at the meal ($P<0.0001$). Subjects ate more vegetables when served the variety than when served any single type; the mean increase was 48±6 g, or more than one-half serving. This increase remained significant when intake of the variety of vegetables was compared to the preferred vegetable of each participant (mean 25±8 g; $P=0.002$). Vegetable intake was not significantly related to energy intake at the meal. The results of this study demonstrate that increasing the variety of low-energy-dense vegetables served at a meal can be used as a strategy to increase vegetable intake.

Keywords

Vegetables; variety; energy density; energy intake; Dietary Guidelines

INTRODUCTION

The United States Department of Agriculture's MyPlate emphasizes the importance of filling0 half the plate with vegetables and fruit[1]. Research has demonstrated that increasing the portion size of a vegetable served on a plate leads to increased vegetable intake[2]. It is possible, however, that serving a large amount of a single type of vegetable may limit intake, because of the development of sensory-specific satiety. This problem might be alleviated by serving several different vegetables, since increasing the variety of available

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foods with different sensory properties can encourage continued consumption and increase intake[3]. The goal of the present study was to determine whether, when filling half the plate with vegetables, offering a variety of vegetables affects intake.

It is well documented that offering a variety of high-energy-dense foods at a meal, whether over successive courses or at the same time, increases food and energy intake[4,5,6,7,8]. During a meal, the pleasantness of the sensory properties declines more for foods already eaten than for those not eaten; this phenomenon is called sensory-specific satiety[9]. When a variety of foods is served, switching from an eaten food to another still palatable food delays the termination of the meal, and this is associated with increased food intake. Although the development of sensory-specific satiety is seen for foods low in energy density, the effects of variety on intake of low-energy-dense foods have not been well investigated[10,11]. It is important to determine whether the variety effect could be used strategically to increase intake of healthy, low-energy-dense foods such as vegetables.

In the present study, the effect of filling half the plate with a variety of three vegetables was compared to that of filling half the plate with each of the vegetables separately. By serving the vegetables individually, intake of the variety of vegetables could be compared to intake of the preferred vegetable. This enabled us to test whether any increased consumption associated with variety occurred because consumers were always able to eat their favorite vegetable, in comparison to a single vegetable that may not have been the favorite. The hypothesis was that serving a variety of vegetables would increase consumption of vegetables at the meal and that the effect would be present even when compared to the most preferred vegetable. A secondary hypothesis was that the increased intake of vegetables would decrease intake of the other more energy-dense food served at the meal and would be associated with a decrease in energy intake at the meal.

METHODS

Study Design

This study used a cross-over design with repeated measures within subjects; thus, participants served as their own controls. Once a week for four weeks, subjects consumed a lunchtime meal ad libitum in the laboratory. Lunch consisted of 600 g of pasta with sauce and 600 g of cooked vegetable, arranged so that each food filled half the plate. On different occasions, the type of vegetables served at the meal was varied: at three meals, one of three single types of vegetable was served and at one meal, 200 g of each of the three vegetables was served side by side. The order of experimental conditions was counterbalanced across subjects using a Latin square.

The vegetables tested in the experiment were broccoli florets (energy density 0.54 kcal/g), baby carrots, (0.33 kcal/g), and snap peas (0.69 kcal/g). To increase the difference in the sensory properties of the vegetables, and since cruciferous vegetables may be considered bitter by some people, the broccoli was flavored with 1.1 g of light butter (Land O'Lakes Inc., St. Paul, MN) and 0.6 g of butter flavoring (Alberto-Culver Co., Melrose Park, IL) per 100 g. The carrots and snap peas were unseasoned. When the vegetables were served individually, the broccoli, carrots, and snap peas provided 324 kcal, 198 kcal and 414 kcal, respectively. When served as a variety, the vegetables provided 312 kcal. The pasta dish was made with creamy tomato sauce (Campbell Soup Co., Camden, NJ; International Gourmet Specialties Co., Pittsburgh, PA) and parmesan cheese (Kraft Foods Inc., Northfield, IL). The energy density of the pasta was 1.57 kcal/g and 942 kcal was served in each condition. The energy content of the foods was assessed by bomb calorimetry (Model 1261, Parr Instrument Co, Moline, IL).

On each test day a standard breakfast was consumed *ad libitum* in order to ensure a consistent level of hunger before each test meal. Subjects returned to the laboratory for lunch at least 3 hours after breakfast. Subjects were instructed to not eat or drink anything except water between breakfast and lunch; compliance with this instruction was monitored by a questionnaire completed before lunch. Lunch was accompanied by one liter of cold water as a beverage.

Participants

Participants were recruited from the Pennsylvania State University and the local community through notices in newspapers and university newsletters. Subjects were eligible for participation if they regularly ate breakfast, lunch, and dinner, had a measured body mass index of 17.5–40 kg/m^2, were not dieting, did not smoke, were not an athlete in training, were not pregnant or breast-feeding, were not using medications known to affect appetite or food intake, had no allergies to study foods, and reported liking and willingness to eat study foods. Exclusion criteria were a score >40 on the Zung Self-Rating Scale[12], which evaluates symptoms of depression or a score >20 on the Eating Attitudes Test[13], which assesses indicators of disordered eating. Subjects provided written informed consent and were financially compensated for their participation. The study protocol was approved by the Office for Research Protections of The Pennsylvania State University.

Sixty-nine subjects were enrolled in the study, which was conducted in 2008 and 2009. Data from three subjects was excluded because of highly variable vegetable intakes that had undue influence on the results according to the procedure of Littell et al.[14]. The restricted maximum likelihood distance (a measure of overall influence) in the mixed linear model was > 2.3 for these subjects. (By excluding these influential subjects, the magnitude of the outcomes was reduced slightly, but the conclusions of the study were unchanged). Thus, 66 subjects were included in the analysis. The 32 men had a mean age of 27.4±1.2 years (range 20 to 45) and a mean body mass index of 25.5±0.6 kg/m^2 (range 20.7 to 35.4); the 34 women had a mean age of 26.5±1.3 years (range 20 to 45) and a mean body mass index of 23.3±0.6 kg/m^2 (range 17.8 to 32.4).

Outcome Assessments

All foods and beverages were weighed before and after meals. Energy intake was calculated using data from food manufacturers and a standard nutrient composition database[15].

Upon arrival for lunch, subjects rated their hunger, fullness, thirst, nausea, and prospective consumption (how much they thought they could eat) using 100-mm visual analog scales[16]. Three minutes later, subjects consumed samples of the three vegetables and the pasta and rated the pleasantness of taste using visual analog scales. After rating the samples, lunch was served. Three minutes after lunch was completed, subjects again rated their hunger, fullness, thirst, nausea, and prospective consumption. After the last lunch meal, subjects completed a brief discharge questionnaire in which they ranked the three vegetables from their most preferred to their least preferred.

Data Analysis

Data were analyzed by a mixed linear model with repeated measures. The fixed effects in the model were the experimental condition (three single vegetables or a variety of all three), subject sex, and study week; subjects were treated as a random effect. The primary outcomes for the study were vegetable intake (g) as well as food (g) and energy intake (kcal) for the entire meal. Secondary outcomes were subject ratings of food characteristics and hunger and satiety. To determine whether the effects of variety on intake were affected by any limitation in the amount of vegetable that was served, participants who consumed >95%

of any portion of vegetables were identified. The outcomes of vegetable intake and meal energy intake were analyzed both with and without these participants. Results are reported as mean ± SEM and were considered significant at $P<0.05$. All statistical analyses were performed using SAS software (version 9.2, 2008, SAS Institute Inc, Cary, NC).

RESULTS AND DISCUSSION

Vegetable intake was significantly affected by the variety and type of vegetable served ($P<0.0001$; Figure 1). Filling half the plate with three different vegetables increased vegetable intake in both men and women compared to serving any of the vegetables individually ($P=0.045$); the average increase was 48±6 g, or more than one-half serving. The effect of variety on intake remained significant ($P=0.002$) when the variety of vegetables was compared to the preferred vegetable for each participant (41 preferred broccoli, 14 peas, and 11 carrots). Compared to the preferred vegetable, the mean increase in consumption was 25±8 g or about one-third of a serving. This was the first study to test the effect of variety on intake of vegetables in adults. The results extend previous research[4–8,10,11] by demonstrating that variety can be used strategically to promote intake of healthy, low-energy-dense foods.

Although increased variety generally leads to an increase in the weight of food eaten, the effect on energy intake is more variable, since it also depends on the energy density of the foods. In the present study, all of the vegetables were low in energy density, but the carrots were the lowest. As a result, energy intake from vegetables was significantly lower when carrots were served alone than at the other meals (Table 1; $P<0.0001$). The major source of calories at the meal, however, was the more energy-dense main dish that filled the other half of the plate. Energy intake from the pasta, and thus the entire meal, did not differ across conditions in women; in men it varied across conditions but was not related to vegetable consumption (Table 1). Additionally, no significant differences were found across conditions in participant ratings of hunger and fullness either before (65.6 ± 1.1 mm and 22.2 ± 1.3 mm, respectively) or after the meal (8.3 ± 0.7 mm and 85.3 ± 0.9 mm, respectively), nor did ratings of thirst, nausea, or prospective consumption differ by condition at either time point. Thus, although vegetable intake increased in the variety condition, this did not lead to increased energy intake at the meal. On the other hand, the amount of extra vegetables did not displace intake of the more energy-dense main dish and reduce meal energy intake. This finding is consistent with a previous study, which found that adding extra vegetables to a meal to fill half the plate increased vegetable consumption by about 60 g but had no significant effect on meal energy intake[2]. It is likely that in the present study, the additional amount of vegetables consumed in the variety condition (approximately 50 g) was insufficient to displace a substantial amount of the main dish. Previous research suggests that relatively large amounts of vegetables (at least 150 g) are required in order to reduce intake of other palatable food at a meal[17].

The inclusion of foods from only one food category, such as vegetables, is likely to limit the effect of variety on intake which depends on the consumer's perception of differences between the foods[3,18]. This perception can be affected by the degree of difference in the sensory properties of the foods, which influences the development of sensory-specific satiety[4,5,6,9,11]. The vegetables tested in this study varied naturally in shape, color, taste, and texture, and were further distinguished by adding flavoring to the broccoli. All the vegetables were well liked, but the taste of the broccoli (72 ± 1 mm) was rated higher than that of the snap peas and carrots (62 ± 1 mm for both; $P<0.0001$); this difference was reflected in greater intake of broccoli ($P=0.0007$; Figure 1). Adding flavoring or sauces can enhance both the palatability of vegetables and the effect of variety, promoting greater consumption[6]. It is important, however, to ensure that such additions do not greatly increase the energy density of vegetables, which could lead to increased energy intake.

Intake at a meal is also dependent on the amount of food served; it has been shown that vegetable intake at a meal is positively related to the portion offered[2]. In the present study, the total amount of vegetable served at the meal was kept the same, in order to allow the examination of the variety effect without confounding by changes in portion size. This design, however, introduced a possible limitation to the study: there was a smaller portion of each type of vegetable in the variety condition than when it was served individually. Thus, the effect of variety could be restricted if an insufficient amount of the most preferred vegetable was available. In the present study, intake remained significantly greater for the variety than for the preferred vegetable after excluding the eight participants who consumed all of any type of vegetable in the variety condition (23 ± 7 g; P=0.002). The portions of vegetables served, however, were generous, and it is important when using variety to enhance vegetable intake to ensure that adequate amounts of preferred vegetables are offered.

In order to ensure that the meal provided adequate amounts of food for both men and women, and that intake was not limited by inadequate portions, the amounts of vegetables and pasta served in this study were larger than many individuals would serve at home. Thus, the findings of this study may be most applicable to settings such as restaurants, where larger portions are typically served. However, it is possible that serving a variety of vegetables in a meal at home would have the same effect, especially if the person preparing and serving the meals served a variety of vegetables that were well-liked by family members. Additional research in various settings is needed to test the effects of increasing the variety of vegetables that are liked to different degrees. Furthermore, the influence of serving a variety of vegetables in the presence of other side dishes and caloric beverages, as in a typical meal, requires investigation.

CONCLUSIONS

This study shows that increasing the variety of healthy low-energy-dense vegetables at a meal can be used strategically to increase their intake. Filling half the plate with a variety of vegetables led to greater consumption than serving a single type of vegetable, even the most preferred one. Although the effect on vegetable intake was significant, it was not large enough to displace intake of the more energy-dense main dish and reduce meal energy intake. This study and those conducted previously indicate that offering a variety of well-liked options with different sensory properties will lead to increased intake. In addition to other meal-based strategies, such as increasing the portion size of vegetables and adding chopped or puréed vegetables to mixed dishes[2,19,20], serving a variety of vegetables that are liked provides an effective way to promote vegetable intake.

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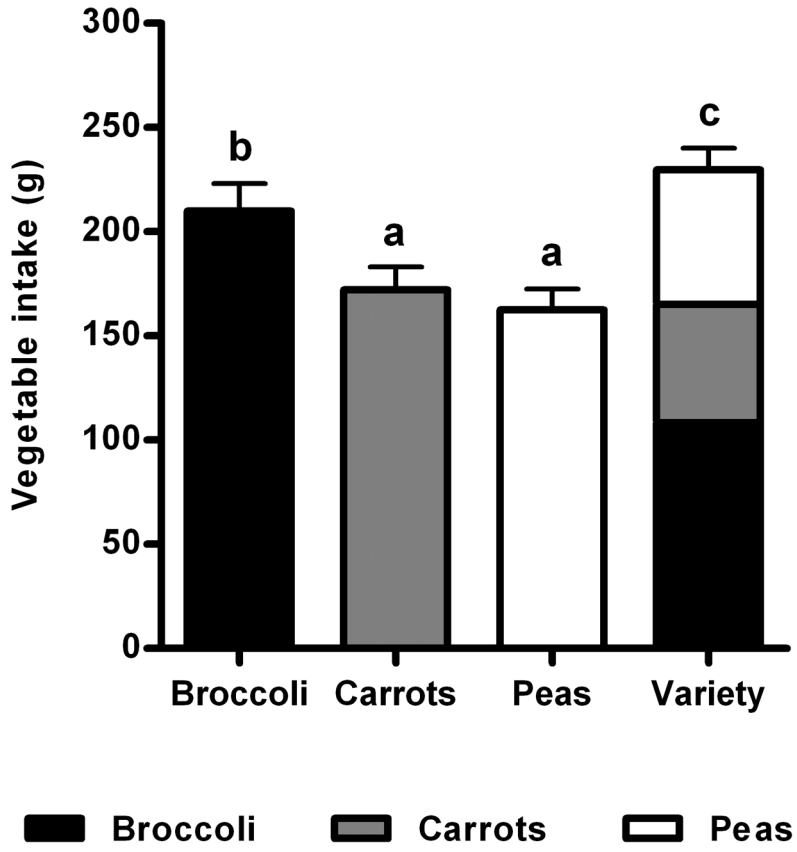

Figure 1.
Mean (±SEM) vegetable intakes of 66 women and men in a cross-over study that tested the effect of filling half the plate with a variety of vegetables at lunch. Means with different letters are significantly different (P <0.045).

Table 1

Food and energy intakes of women and men in a cross-over study that tested the effect of filling half the plate with a variety of vegetables at lunch

	Vegetable condition			
Meal intake	**Broccoli**	**Carrots**	**Peas**	**Variety[a]**
	mean ± standard error of the mean			
Women (n=34)				
Vegetable intake (g) [b]	203 ± 15	176 ± 12	164 ± 12	232 ± 13
Pasta intake (g)	309 ± 17^{x}	334 ± 20^{x}	308 ± 18^{x}	307 ± 17^{x}
Total meal intake (g) [c]	512 ± 24	510 ± 26	473 ± 26	539 ± 25
Vegetable energy (kcal) [d]	109 ± 8	58 ± 4	114 ± 8	123 ± 8
Pasta energy (kcal)	485 ± 27^{x}	524 ± 31^{x}	484 ± 29^{x}	481 ± 27^{x}
Total meal energy (kcal)	594 ± 29^{x}	582 ± 33^{x}	598 ± 34^{x}	604 ± 30^{x}
Men (n=32)				
Vegetable intake (g) [b]	217 ± 22	168 ± 19	160 ± 16	227 ± 17
Pasta intake (g)	372 ± 22^{x}	402 ± 22^{xy}	424 ± 22^{y}	416 ± 21^{y}
Total meal intake (g) [c]	590 ± 36	571 ± 36	584 ± 32	643 ± 30
Vegetable energy (kcal) [d]	116 ± 12	55 ± 6	111 ± 11	119 ± 10
Pasta energy (kcal)	584 ± 35^{x}	632 ± 34^{xy}	665 ± 34^{y}	653 ± 33^{y}
Total meal energy (kcal)	701 ± 40^{x}	687 ± 38^{x}	776 ± 40^{y}	772 ± 37^{y}

[a] The variety condition consisted of equal amounts of broccoli, carrots, and peas; across conditions, the total weight of vegetables served was kept the same.

[b] Main effect of condition on vegetable intake (P<0.0001). Pairwise differences: carrots & peas < broccoli < variety (P<0.045).

[c] Main effect of condition on meal intake (P<0.0001). Pairwise differences: broccoli, carrots, & peas < variety (P<0.032).

[d] Main effect of condition on vegetable energy intake (P<0.0001). Pairwise differences: carrots < broccoli, peas, & variety (P<0.0001).

[x,y] Interaction of condition and sex (P<0.025). Means in the same row with different superscript letters are significantly different (P<0.05).