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New Metrics of Affordable Nutrition: Which Vegetables Provide Most Nutrients for Least Cost?

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ABSTRACT

Measuring food prices per gram, rather than per calorie, is one way to make healthful vegetables appear less expensive. However, a better measure of affordability would take the nutrient content of vegetables into account. This study, based on analyses of US Department of Agriculture datasets, aimed to identify which vegetables, including juices and soups, provided the most nutrients per unit cost. Nutrient density was measured using the Nutrient Rich Foods (NRF) index, based on nine nutrients to encourage: protein; fiber; vitamins A, C, and E; calcium; iron; magnesium; and potassium; and on three nutrients to limit: saturated fat, added sugar, and sodium. Food cost in dollars was calculated per 100 g, per 100 kcal, per serving, and per nutrient content. One-way analyses of variance with post hoc tests were used to determine statistical significance. Results showed that tomato juices and tomato soups, dark green leafy and nonleafy vegetables, and deep yellow vegetables, including sweet potatoes, had the highest NRF scores overall. Highest NRF scores per dollar were obtained for sweet potatoes, white potatoes, tomato juices and tomato soups, carrots, and broccoli. Tomato sauces, raw tomatoes, and potato chips were eaten more frequently than were many other vegetables that were both more affordable and more nutrient-rich. These new measures of affordable nutrition can help foodservice and health professionals identify those vegetables that provide the highest nutrient density per unit cost. Processed vegetables, including soups and juices, can contribute to the quality and the affordability of the diet.
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CURRENT DIETARY RECOMMENDATIONS, INCLUDING the 2010 Dietary Guidelines, have stressed the important contribution of vegetables to a healthy diet.[1] The US Department of Agriculture (USDA) ChooseMyPlate program recommends that half of the plate be composed of vegetables and fruit.[2] Eating a variety of vegetables, especially dark green, red, and orange vegetables, would help Americans meet nutrient requirements while staying within their calorie needs.[1,3]

The cost of healthy eating has become a growing concern.[4-9] Given current food prices, food patterns higher in fruit and vegetable content have been generally associated with higher diet costs.[10-14] A recent USDA report suggested that vegetables would seem cheaper to consumers if their prices were measured per gram rather than per calorie.[15] However, food prices per gram do not reflect differences in the foods' moisture content and therefore energy density, which can vary widely within the vegetables group. Conversely, food prices per calorie do not reflect differences in the vegetables' content of vitamins and minerals. Measures of affordable nutrition ought to assess the amounts of beneficial nutrients per unit cost.[10]

The Affordable Nutrition Index (ANI), a measure of nutrients per unit cost, was specifically designed to identify those foods that provide the most nutritional value for the least money.[16] Its creation was made possible by two methodological advances. First, the overall nutritional quality of different vegetables was assessed using the Nutrient Rich Foods (NRF) index.[17,18] Second, the most recent USDA national food prices database was used to examine the nutritive value of different vegetables in relation to their cost.[19,20]

Because of their production and market costs, vegetables are expensive sources of calories; however, they can be very affordable sources of several key nutrients.[21] Our goal was to compare different vegetables, including fresh, frozen, and processed, in terms of their nutrient content and value for money. The ANI was the principal dependent variable.

METHODS

Calculation of the NRF Index

The Nutrient Composition Database. The Food and Nutrient Database for Dietary Studies (version 2.0, 2006, US Department of Agriculture) (FNDDS 2.0) was used to code, process, and analyze the What We Eat in America food intake data for 2003-2004.[22] The files included detailed food descriptions for >6,940 foods from all food groups, typical food portions and weights, method of preparation (where available), and nutrient values for energy and 60 nutrients. Each food was identified by a unique eight-digit code, where the first digit identified the major food group. The second digit identified subgroups (white potatoes, dark green vegetables, deep yellow vegetables, tomatoes, and other vegetables),

whereas the third and subsequent digits provided ever-finer discrimination down to the individual food item. The FNDDS database also specified whether the vegetables were consumed cooked or raw; whether they were cooked from fresh, frozen, or canned; or whether the form of vegetable was not further specified. Canned and bottled vegetable juices and vegetable soups were included in the vegetables group. FNDDS 2.0 generally does not provide brand names and the vast majority of the items in the vegetable group were generic.

Exclusion Criteria. The analyses were limited to foods consumed by National Health and Nutrition Examination Survey (NHANES) 2003-2004 participants (ie, frequency of consumption >1).[23] The merged database was edited to remove all duplicate lines, infant and baby foods, alcohol, and mixed dishes with meat. Foods that cost between $0 and $0.02/100 g were excluded. The final analyses were based on a total of 2,876 foods in nine major food groups, including 608 items in the vegetables group.

NRF Index. The previously developed and validated NRF index is the sum of percent daily values (%DVs) for nine nutrients to encourage minus the sum of percent daily values for three nutrients to limit, with all DVs calculated per serving size.[17]

Six of the nutrients to encourage (protein, fiber, vitamins A and C, calcium, and iron) were derived from the Food and Drug Administration (FDA) definition of healthy foods. Fiber, calcium, and potassium were listed as nutrients of public health concern in the 2010 Dietary Guidelines for Americans.[1] Saturated fat, added sugar, and sodium[24,25] were the nutrients to limit. Reference Daily Values were based on FDA standards.[24,26] The algorithms for the calculation of NRF indexes have been published.[18]

All amounts were converted to %DV per 100 kcal or per Reference Amount Customarily Consumed (RACC). RACC values are set lower for energy-dense fats and oils (15 g) than for most vegetables (85 g), juices or soups (245 g). Percent DVs were capped at 100% so that foods containing very large amounts of a single nutrient would not obtain a disproportionately high NRF score.[18]

Calculation of the ANI

The Food Price Database. The updated Center for Nutrition Policy and Promotion food price database was based on information from multiple sources, including the Nielsen Homescan Consumer Panel. To arrive at food prices, foods reported as consumed by NHANES 2003-2004 participants were disaggregated into components and yield factors were applied to individual ingredients and to the entire dish. This procedure converted foods-as-consumed to foods-as-purchased, with purchase prices obtained from the Nielsen panel. One national price, corrected for preparation and waste and expressed per gram of edible portion, was provided for each food in the NHANES database.[23] All foods used the same eight-digit code as the FNDDS 2.0.

The USDA FNDDS 2.0 database was merged with the Center for Nutrition Policy and Promotion food prices database and customized further to include added sugars from the USDA Pyramid Servings Database. FDA-mandated serving sizes were based on the RACC.

ANI. The affordability of foods can be measured in terms of nutrient density per dollar. First, the NRF index for individual foods was calculated per serving. NRF values were then divided by the national price per serving for that food. ANI affordability scores were calculated for vegetables and vegetable subgroups, as defined by the FNDDS 2.0 eight-digit food codes.

Frequency of Consumption

Frequency of consumption (Days 1 and 2) was obtained from food listings in the NHANES 2003-2004 database.[23] The frequency measure is merely an index of use by the population and does not reflect portion size. For example, raw tomatoes appeared in the database 3,391 times (most likely as garnish), tomato catsup appeared 3,254 times, whereas tomato juice appeared 38 times.

Statistical Analyses

All analyses were performed using the Statistical Package for the Social Sciences version 11.0 (2002, IBM Corp). Spearman correlations and univariate comparisons of means across quintiles were the principal analyses performed. An α level of .05 was used to determine statistical significance.

RESULTS AND DISCUSSION

Vegetables vs the Other Food Groups

The relation between the mean NRF nutrient density score and mean water content of nine major US food groups are shown in Figure 1. The size of the bubble corresponds to the mean frequency of occurrence reported in the two 24-hour food recalls in NHANES 2003-2004.[23] Analyses based on one-way analysis of variance followed by Scheffé tests confirmed that the vegetable group had significantly higher NRF scores per serving compared with every other major food group other than the fruits group and the dry beans, legumes, nuts, and seeds group (data not shown).

However, the nutrient-dense vegetables were not the foods that were most frequently consumed by NHANES participants. The mean reported frequency of occurrence of the sugars, sweets, and beverages group and the fats, oils, and salad dressings group over the 2-day period exceeded the mean frequency of occurrence of foods in the fruits group; the meat, poultry, and fish group; and the dry beans, legumes, nuts, and seeds group.

Vegetable Prices per 100 g, per 100 kcal, and per Serving

Mean energy density, water content, and relative prices per 100 g, per 100 kcal, and per serving for five vegetable subgroups are shown in the Table. It can be seen that white potatoes (including fried) had the lowest water content and the highest energy density. One-way analysis of variance, followed by Scheffé tests, confirmed that white potatoes were significantly different from every other group in terms of energy density and water content ($P<0.001$). By contrast, dark green vegetables (including leafy greens)