The Nutrient Rich Foods Index helps to identify healthy, affordable foods[1–4]

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ABSTRACT

Background: The Nutrient Rich Foods (NRF) Index is a formal scoring system that ranks foods on the basis of their nutrient content. When used in conjunction with a food prices database, it can help identify foods that are both nutritious and affordable.

Objective: Our aim was to identify healthy, affordable foods and food groups by using the NRF index and US Department of Agriculture (USDA) nutrient composition and food prices data sets.

Design: Foods in the USDA Food and Nutrition Database for Dietary Studies 1.0 were scored by using the NRF index. This NRF algorithm was represented by the sum of the percentage of the daily values of 9 nutrients to encourage (protein, fiber, vitamin A, vitamin C, vitamin E, calcium, iron, magnesium, and potassium) minus the sum of the percentage of the maximum recommended values for 3 nutrients to limit (saturated fat, added sugar, and sodium). NRF scores and mean national food prices were calculated per calorie and per US Food and Drug Administration–defined serving.

Results: Each of the 9 USDA food groups offered foods of diverse nutritive value and cost. Eggs, dry beans and legumes, and meat and milk products were the lowest-cost sources of protein. Milk and milk products were the lowest-cost sources of calcium, whereas vegetables and fruit were the lowest-cost sources of vitamin C. Milk, potatoes, citrus juices, cereals, and beans had more favorable overall nutrient-to-price ratios than did many vegetables and fruit. Energy-dense grains, sweets, and fats provided most of the calories but fewer nutrients per dollar.

Conclusion: One important application of nutrient profile models is to help consumers identify foods that provide optimal nutrition at an affordable cost.   *Am J Clin Nutr* 2010;91(suppl):1095S–101S.

INTRODUCTION

The concept of nutrient density was the cornerstone of the 2005 Dietary Guidelines and US Department of Agriculture (USDA) MyPyramid (1, 2). Americans were advised to get the most nutrition out of their calories and to make smart, nutrient-dense choices from every food group. The Nutrient Rich Foods (NRF) Index (3, 4), a new instrument to measure nutrient density, was developed as an integral part of a comprehensive system of nutrition education and guidance (5, 6).

The NRF approach emphasizes nutrient density, defined as nutrients per calorie, as the key component of dietary advice (7, 8). NRF algorithms can be readily applied to individual foods, meals, and menus—or to the total diet. In published analyses of National Health and Nutrition Examination Survey (NHANES) data sets, diets awarded higher NRF scores were associated with

higher consumption of foods and nutrients to encourage, higher Healthy Eating Index values, and lower energy intakes overall (4). The documented links between nutrient-rich foods, overall diet quality, and health outcomes are what distinguishes the NRF index from other food scoring systems used to create front-of-package logos or supermarket shelf labels.

The current NRF algorithm, based on 9 nutrients to encourage and 3 nutrients to limit, is known as NRF9.3. The present unique innovation lies in using the NRF index to calculate optimal nutrition per food dollar. Nutrient-profiling models are useful insofar as they help consumers create healthier diets. Ideally, the recommended highest-scoring foods ought to be nutrient dense, as well as affordable and appealing (9, 10). Linking the USDA Center for Nutrition Policy and Promotion national food prices data (11) with the Food and Nutrient Database for Dietary Studies (FNDDS) nutrient composition database (12) has allowed us to study the nutrient density of US foods in relation to their cost.

Studies on the nutritive value of foods in relation to cost are a direct legacy of Wilbur Atwater (13). Widely credited with the development of agricultural and human nutrition research in the United States (14, 15), Atwater aimed to assist people in making more nutritious food choices subject to economic constraints (14). In his view, a combination of food prices data, nutrient composition tables, and the knowledge of people's food habits was the basis for advising the public on how to purchase the most economical diets (14, 16).

Identifying the most economical foods posed a problem. The difficulty, according to Atwater, was that, in comparing the cost of different foods, people were apt to judge them by the "prices per pound, quart, or bushel" without regard to the amounts or the kinds of nutrients that they actually contained (13). His solution was to ignore package sizes and determine instead the relative

amounts of protein, fat, carbohydrate, and calories that could be obtained for a fixed monetary cost. Atwater's 1894 article in the *Farmers' Bulletin* (13) listed the amounts of calories and macronutrients that could be obtained from different foods for 25 cents. Vitamins had not yet been discovered. The lowest-cost calories came from wheat flour, corn meal, sugar, salt pork, potatoes, and beans (13). That article marked the beginning of food and nutrition policy in the United States.

Nutrient profiling, based on macro- and micronutrients as well as on calories, provides the modern tools that Atwater lacked (3, 17–19). Closely following the US regulatory structure (20, 21) and dietary guidelines (1), the NRF9.3 index is based on 9 nutrients to encourage (including multiple vitamins and minerals) and 3 nutrients to limit (3, 4). When coupled with food prices, the NRF9.3 index can help consumers identify foods that are both healthy and affordable. None of the current nutrient-profiling schemes have as yet been used for that important purpose.

Since Atwater's time, the USDA has continued to examine the cost of a nutritious diet (22–24). Studies of food plans for consumers at different levels of income have explored trade-offs among nutrition standards, food preferences, and food costs with a view to creating affordable yet nutrient-rich diets for US population subgroups (24). There is a pressing need to integrate the USDA-led economic research and food policy literature with mainstream epidemiologic studies on diet and chronic disease risk (25–27). Adherence to dietary guidelines for the prevention of cancer, obesity, or cardiovascular disease can be influenced by social, educational, and material resources, but it can also depend on food prices and diet costs (26–29). Developing nutrient profile models to help consumers identify affordable nutrient-rich foods across and within food groups has implications for nutrition education, food policy, and public health.

METHODS

Nutrient and food price databases

Nutrient composition database

The USDA FNDDS 1.0 is used to code, process, and analyze the "What We Eat in America" food intake data (12). The files include detailed food descriptions for 6940 foods from all food groups, typical food portions and weights, method of preparation (where available), nutrient values for energy and 60 nutrients, and links to the USDA Standard Release nutrient composition databases (30). The primary description of a food is linked to a unique 8-digit identification code. The first digit in the code identifies 1 of the 9 major USDA food groups: *1)* milk and milk products; *2)* meat, poultry, and fish; *3)* eggs; *4)* dry beans, legumes, nuts, and seeds; *5)* grain products; *6)* fruit; *7)* vegetables; *8)* fats, oils, and salad dressings; and *9)* sugars, sweets, and beverages. The second digit identifies subgroups within each major food group (eg, milk and milk drinks, creams, cheeses, and milk desserts), including mixed foods, whereas the third and subsequent digits provide ever-finer discrimination down to the individual food item.

Food price database

The USDA Center for Nutrition Policy and Promotion food price database, released in May 2008 (11), was based on information from the 2001–2002 NHANES study, the FNDDS 1.0, the National Nutrient Database for Standard Reference (SR16.1 and -18), and the Nielsen Homescan Consumer Panel. To arrive at food prices, foods reported as consumed by 2001–2002 NHANES 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 Homescan Consumer Panel. One national price, corrected for preparation and waste and expressed per gram of edible portion, was provided for each food that was listed as consumed at least once in the NHANES database (ie, where frequency of consumption was >1). All foods used the same 8-digit code as used by the FNDDS 1.0.

For this study, the USDA FNDDS 1.0 database (12) was merged with the Center for Nutrition Policy and Promotion food prices (11). The merged database was customized further to include added sugars from the USDA Pyramid Servings Database, as described before (4). Common food portions provided in the FNDDS were replaced with US Food and Drug Administration (FDA)-mandated serving sizes, ie, Reference Amounts Customarily Consumed (RACC). The FDA uses 139 different values for serving sizes, obtainable from lists of FDA standards (21). RACC values are set lower for energy-dense sugar (4 g), fats and oils (15 g), and cheeses (30 g) than for meats (85 g), vegetables and fruit (120 g), or milk, juices, and other beverages (240 g). FDA documentation (21) shows that serving sizes vary enormously both across and within food groups. A single serving of food can weigh from 1 to 458 g and can provide between 1 and >1000 kcal.

Exclusion criteria

The present analyses were limited to those foods for which the frequency of consumption listed in the NHANES database was >5 eating occasions. On the basis of the second- and third-digit codes used, infant formulas, baby foods, alcohol, and mixed foods were removed. Also removed were such foods as human milk, dry flour and biscuit mixes, intense sweeteners and nondairy creamers, chewing gum, and therapeutic formulas including electrolyte solutions and meal replacements. The merged database was edited further to remove all duplicate lines, to remove items for which no further specification (NFS) was provided (eg, "meat, NFS" or "sandwich, NFS)," to remove other nonspecific (NS) items (eg, "vegetable, NS as to type"), and to remove foods in which fat added during preparation was not specified ("fat, NS"). To allow calculations of nutrient density and cost per 100 kcal, bottled water (0 kcal) and diet foods and diet beverages with energy density close to zero (<10 kcal/100 g) were excluded. Foods that cost between 0 and 5 cents/100 g were also excluded so they would not have a disproportionate influence when price was in the denominator. The final analyses were based on a total of 1387 foods, representing all 9 major USDA food groups.

Nutrient Rich Foods Index

The NRF index provides a validated metric to assess nutrient density of individual foods (3, 4). The present variant, known as NRF9.3, was based on the sum of the percentage of daily values for 9 nutrients to encourage minus the sum of the percentage of maximum recommended values for 3 nutrients to limit, with all daily values calculated per 100 kcal and capped at 100% (4).

Alternative versions of the NRF algorithm were based on a variable number of nutrients to encourage ($n = 5–23$) and the same 3 nutrients to limit.

The choice of nutrients to encourage followed the FDA definition of "healthy foods," which is based on the foods' content of protein, fiber, vitamins A and C, calcium, and iron. The additional nutrients—vitamin E, potassium, and magnesium—were identified as nutrients of concern by the 2005 Dietary Guidelines for Americans (1, 3, 7). Nutrients to limit were saturated fat, added sugar, and sodium, which is consistent with systems used in the United Kingdom (31) and in France (9). Foods are disqualified from nutrition and health claims in the United States if they contain above-specified amounts of fat, saturated fat, *trans* fat, cholesterol, and sodium (4, 20).

Daily Reference Values were based on FDA standards, as shown in **Table 1** (20, 21). For nutrients to limit, maximum recommended values were 20 g for saturated fat, 125 g for total sugar, 50 g for added sugar, and 2400 mg for sodium in a 2000 kcal/d diet, as based on a variety of sources (4). All amounts were converted to the percentage of daily values per 100 kcal or per serving size, defined as the FDA reference amount customarily consumed or the RACC.

The NRF9.3 index calculated per 100 kcal was independent of serving size. For present purposes, NRF indexes were calculated per 100 kcal and per RACC. The percentage of daily values was capped at 100% so that foods containing very large amounts of a single nutrient would not obtain a disproportionately high index score (4).

The simplest NRF algorithms tested were a combination of positive NR9 and negative LIM subscores. The optimal NRF9.3 algorithm, shown in **Table 2**, was calculated per 100 kcal and per RACC. The sum of the percentages of daily values for 9 nutrients to encourage was the NR9 subscore, whereas the sum of maximum recommended values for 3 nutrients to limit was the LIM subscore. NR9 minus LIM yielded the NRF9.3 score. In deciding on the optimal algorithm, food scores obtained by using alternative NR, LIM, and NRF indexes were compared with the foods' energy density (kcal/100 g), energy cost ($/100 kcal), and Healthy Eating Index values, as outlined in previous research (4, 32, 33). Dividing positive NRF9.3 scores by cost per reference amount yielded the current measure of affordable nutrition.

TABLE 1
Reference daily values and maximum recommended values for nutrients based on a 2000-kcal diet[1]

Nutrient	RDV	MRV
Protein (g)	50	—
Fiber (g)	25	—
Vitamin A (IU)	5000	—
Vitamin C (mg)	60	—
Vitamin E [IU (mg)]	30 (20)	—
Calcium (mg)	1000	—
Iron (mg)	18	—
Potassium (mg)	3500	—
Magnesium (mg)	400	—
Saturated fat (g)	—	20
Added sugar (g)	—	50
Sodium (mg)	—	2400

[1] RDV, reference daily value; MRV, maximum recommended value.

Statistical analyses

All analyses were performed by using the Statistical Package for the Social Sciences version 11.0 (SPSS Inc, Chicago, IL). Analyses of variance, regression models, and univariate comparisons of means across quintiles were the principal analyses performed. An α of 0.05 was used to determine statistical significance.

RESULTS

Energy costs by USDA food group

Serving sizes were not uniform across food groups. Following Atwater's precedent, the measure of calories per unit cost was obtained by dividing calories per serving (kcal/RACC) by the applicable price in dollars per serving ($/RACC), both of which were obtained from USDA nutrient composition and price databases. RACC values are set by the FDA. Mean and median calories per unit cost for each of the 9 major USDA food groups are shown in **Figure 1**. One-factor analysis of variance showed strong and significant effects of food group: $F(8, 1378) = 52.42$; $P < 0001$. Post hoc multiple comparisons using Dunnett's tests and Bonferroni correction showed that vegetables and fruit provided significantly fewer calories per unit cost as compared with fats and oils, grains, sugars and sweets, dry beans and legumes, and milk and milk products. At the other extreme, fats and oils provided significantly more calories per unit cost than every other food group.

In 1894, Atwater used a very similar horizontal bar graph to show the amounts of energy that could be obtained from different foods for 25 cents (13). It has not escaped our attention that fats and oils, grain products, dry beans and legumes, and sugars and sweets are, for the most part, higher in energy per unit volume (kcal/g) than are vegetables and fruit.

Nutrient costs by USDA food group

Atwater's major problem was lack of information about the nutritive value of food. In the absence of vitamins, the 1894 tables were limited to the amounts of energy, protein, carbohydrate, and fats, corrected for waste, that could be obtained for 25 cents (13). Median costs in dollars of obtaining 100% of daily value for selected nutrients from each of the 9 food groups are shown in **Table 3**. The nutrients selected were a part of the NRF9.3 model (protein, fiber, vitamins A and C, calcium, iron, and potassium) or were outside the model (riboflavin, zinc, and vitamin B-12) but are thought to contribute to a healthy diet. The intent was to show that the balanced nutrient-rich diets could be achieved at low cost by incorporating foods from every food group.

All main effects by food group were statistically significant ($P < 0.01$). Eggs, meat, milk, and dry beans and legumes were the lowest cost sources of protein. Eggs, meat, and milk products are the chief dietary sources of complete high-quality protein. Eggs and milk were also the lowest-cost sources of vitamin A. Dry beans, nuts, and seeds were the lowest-cost sources of fiber. Vegetables and fruit were the lowest-cost sources of vitamin C. Milk products were the lowest-cost source of dietary calcium, followed by eggs. Eggs, milk products, and meat were the lowest-cost sources of vitamin B-12. Grains, dry beans, and eggs were the lowest-cost sources of iron. Vegetables and dry beans

TABLE 2
Nutrient Rich Foods (NRF) Index algorithms for nutrient-rich (NR9) and limiting nutrients (LIM) subscores and for the composite NRF9.3 nutrient profile model[1]

Model	Algorithm	Notes
NR9 subscore[2]		
$\quad$ NR9$_{RACC}$	Σ_{1-9} (nutrient$_i$/DV$_i$) $\times$ 100	Nutrient$_i$ = nutrient per serving (weight)
		DV$_i$ = daily value for the nutrient (weight)
$\quad$ NR9$_{100\ kcal}$	Σ_{1-9} (nutrient$_i$/DV$_i$)/S$_i$ $\times$ 100	S$_i$ = calories per serving
LIM subscore[3]		
$\quad$ LIM$_{RACC}$	Σ_{1-3} (nutrient$_i$/MRV$_i$)/S$_i$ $\times$ 100	Nutrient$_i$ = nutrient per serving (weight)
		MRV$_i$ = maximum recommended value for the nutrient (weight)
$\quad$ LIM$_{100\ kcal}$	Σ_{1-3} (nutrient$_i$/MRV$_i$)/S$_i$ $\times$ 100	S$_i$ = calories per serving
NRF composite model		
$\quad$ NRF9.3$_{RACC}$	NR9$_{RACC}$ − LIM$_{RACC}$	—
$\quad$ NRF9.3$_{100\ kcal}$	NR9$_{100\ kcal}$ − LIM$_{100\ kcal}$	—

[1] RACC, reference amount customarily consumed.
[2] NR9 subscore based on 9 nutrients to encourage.
[3] LIM subscore based on 3 nutrients to limit.

were the lowest-cost sources of potassium. Dry beans and eggs were the lowest-cost sources of zinc. Eggs, grains, and milk were the lowest-cost sources of riboflavin. In other words, lowest-cost nutrients to encourage were obtained from diverse animal and plant foods. The group of sugars, sweets, and sweetened beverages was not a low-cost source of any of the nutrients listed, with the exception of vitamin C in fortified beverages. All calculations were based on those foods within the food group that contained the nutrient in question.

Nutrient density and energy cost

Subsequent analyses examined the relation between overall nutrient density of foods, as assessed by using the NRF index, and their energy cost (kcal/100 g). The separate NRF index scores for each food group, plotted against the median energy density for that group, are shown in **Figure 2**. Sweets, sugars, and beverages scored lowest on the NRF index, whereas fruit, vegetables, dry beans and legumes, and eggs scored highest, followed by meat, poultry, and fish. However, the vegetable and fruit groups—but not the egg or bean groups—were also associated with higher energy costs, defined as dollars per 100 kcal. It can be seen that
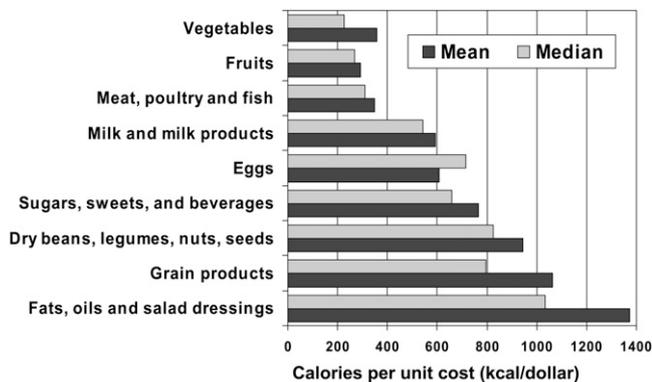

FIGURE 1. Mean and median calories per unit cost (kcal/$) for 9 major food groups in the US Department of Agriculture Food and Nutrient Database for Dietary Studies 1.0 nutrient composition database ($n = 1387$). The variable was calculated by dividing calories per serving by dollar price per serving.

eggs, dry beans, legumes, nuts, and seeds provided exceptional nutritional value for the money.

Subsequent analyses were based on individual foods, as identified by the 8-digit code. A NRF index score was assigned to each of the foods in the FNDDS database, regardless of food group or subgroup. The scores were then split into 5 equal groups or quintiles. The relation between means and medians of the NRF index scores by quintile and calories per dollar is shown in **Figure 3**. A comparison of means, conducted by using one-factor analysis of variance, showed that the main effect of quintiles was significant: $F(4.1382) = 126.8; P < 0.001$. Foods in the bottom quintile of NRF index scores, which were mostly fats and sweets, were associated with more calories per dollar, whereas foods in the top quintile of NRF index scores, which were mostly vegetables and fruit, were associated with significantly fewer calories per dollar.

Finding affordable nutrient-rich foods within food groups

The nutritive value of foods can vary widely within a food group. For example, the milk and milk products group included milk and milk drinks, creams, cheeses, and milk desserts. The vegetables group included a wide range of fresh and canned produce as well as sweet potatoes and white potatoes. The fruit group included fresh and canned fruit, dried fruit, and fruit juices of different energy density and added sugar content. The next level of analysis was therefore based on selected food subgroups defined by the second digit of the 8-digit USDA food identification code. The NRF index scores were calculated on the basis of 100 kcal and on serving size. The Center for Nutrition Policy and Promotion food prices for each food subgroup were converted to dollars per serving and per 100 kcal. Median NRF index scores, median costs, and median energy densities for the food subgroups are summarized in **Table 4**.

Analyses of nutritive value showed that citrus juices, milk, fish and shellfish, beef steak, cooked and ready-to-eat cereals, beans and nuts, vegetables, and chicken all had higher NRF index scores than did cakes and cookies, lunch meats, or desserts. Similar results were obtained whether the NRF algorithm was based on serving size or on 100 kcal of food. Dividing the NRF

TABLE 3
Median and mean estimated costs in dollars of 100% daily value of selected nutrients as provided by major US Department of Agriculture (USDA) food groups, based on Food and Nutrient Database for Dietary Studies 1.0 nutrient composition and Center for Nutrition Policy and Promotion food price databases[1]

	USDA food group								
Nutrients	Milk and milk products (n = 134)	Meat, poultry, fish (n = 196)	Eggs (n = 8)	Dry beans, legumes, nuts, seeds (n = 62)	Grain products (n = 435)	Fruit (n = 92)	Vegetables (n = 257)	Fats, oils, salad dressings (n = 51)	Sugars, sweets, beverages (n = 151)
Protein	2.19 (2.83)	1.87 (2.05)	0.99 (1.77)	1.47 (1.98)	3.09 (4.95)	22.3 (35.4)	6.77 (9.61)	17.7 (29.4)	14.3 (50.1)
Fiber	6.94 (16.9)	33.0 (44.1)	—	1.52 (3.34)	3.81 (6.42)	5.46 (12.9)	3.38 (4.62)	17.7 (42.9)	8.14 (16.9)
Vitamin A	4.50 (13.4)	51.5 (195)	1.95 (5.42)	68.5 (203)	10.5 (55.7)	82.1 (168)	10.2 (46.9)	9.73 (103)	50.7 (174)
Vitamin C	24.5 (32.8)	45.2 (65.2)	—	8.62 (36.8)	22.1 (77.2)	1.48 (6.85)	1.52 (3.82)	60.9 (67.6)	14.3 (61.4)
Calcium	1.53 (2.12)	36.5 (51.4)	3.81 (8.17)	7.15 (9.96)	6.91 (14.1)	23.3 (31.9)	10.4 (27.7)	17.3 (26.7)	18.0 (36.7)
Iron	28.3 (37.9)	8.57 (12.0)	3.15 (10.4)	3.32 (4.02)	2.28 (3.34)	13.0 (21.8)	6.93 (9.70)	21.6 (42.4)	17.7 (46.6)
Potassium	5.70 (10.7)	9.62 (10.7)	5.48 (7.31)	2.64 (5.15)	9.15 (13.2)	5.90 (9.30)	4.09 (8.07)	23.7 (53.8)	11.6 (64.6)
Zinc	4.66 (6.75)	4.46 (7.80)	3.05 (20.3)	2.69 (3.60)	6.18 (9.04)	39.0 (47.5)	11.8 (19.0)	25.7 (44.8)	36.7 (76.2)
Vitamin B-12	3.91 (5.08)	5.57 (8.54)	1.47 (5.32)	24.4 (33.9)	10.8 (36.8)	—	12.6 (34.2)	14.6 (23.4)	15.7 (26.0)
Riboflavin	2.52 (2.83)	6.35 (10.2)	0.92 (1.31)	6.00 (7.35)	2.22 (3.37)	15.3 (21.7)	7.28 (10.6)	15.3 (26.9)	12.4 (40.9)

[1] All values are medians; means in parentheses.

index score per serving by the cost per serving was the chosen approach to identifying the most affordable nutrient-rich food subgroups. Foods that offered high nutrient density were not always the most economical choices: for example, the high nutritional density of shellfish was more than offset by its high cost, such that beef provided better nutritional value for money. In terms of nutrients per unit cost, highest values were obtained for citrus juices, milk, fortified ready-to-eat cereals, potatoes, cooked cereals, vegetables, fruit, and eggs. Many of these foods offered high nutrient density as well as high value for money.

DISCUSSION

Nutrient profiling can identify the most nutrient-rich food subgroups (or individual foods) within each USDA food group. In the United States, nutrient profiling has been used to create shelf labels and front-of-package logos to convey the nutritional value of foods to the consumer simply and at a glance. Whether the introduction of such labeling schemes at the point of purchase

will lead to measurably healthier diets is not yet clear. Nutrient profiling might be more usefully applied to novel systems of nutrition education and food guidance.

One major influence on food selection is food cost. Nutrient-profiling systems, when coupled with food-price data, can help consumers identify foods that are both affordable and nutritious. Different food groups were associated with different amounts of calories per dollar as shown in Figure 1. Quintiles of nutrient density, as indexed by the NRF score, were also associated with different amounts of calories per dollar as shown in Figure 3. In general, grains, fats, and sweets supplied cheaper calories than did vegetables and fruit.

The present application took advantage of the NRF9.3 to assess the nutritive value of individual foods (3, 4). The NRF index takes into account 9 nutrients to encourage, including vitamins and minerals, and 3 nutrients to limit. Positive NRF scores were then divided by food prices per reference amount (per serving or 100 kcal) to determine the relative amounts of nutrients per dollar. Among the highest-scoring foods and food groups were citrus fruit and juices, milk, fortified ready-to-eat cereals,
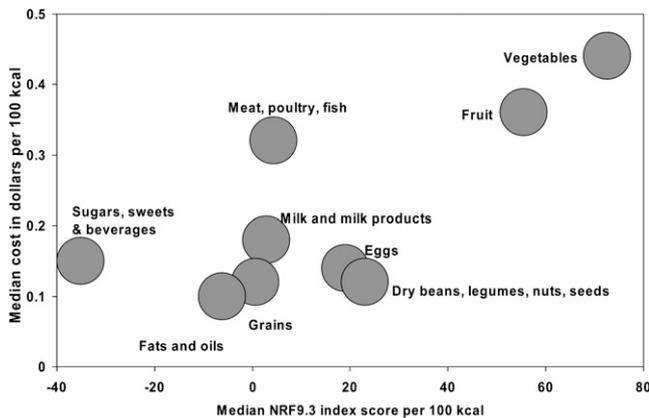

FIGURE 2. Median Nutrient Rich Foods (NRF9.3) Index scores for each major US Department of Agriculture food group plotted against median cost per 100 kcal. Higher NRF index scores denote higher nutrient density per 100 kcal.
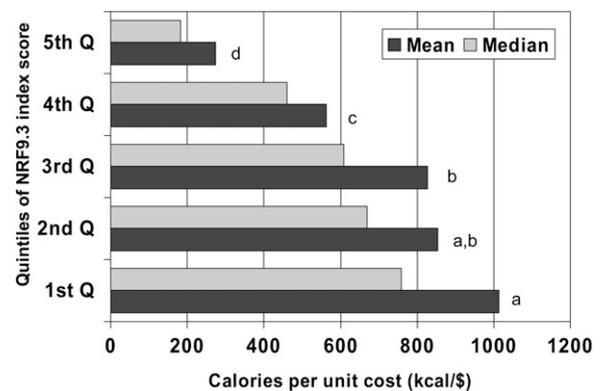

FIGURE 3. Quintiles of Nutrient Rich Foods (NRF9.3) Index scores plotted against mean and median calories per unit cost (kcal/$). Higher NRF index score quintiles denote higher nutrient density per 100 kcal. Values with the same letters are not significantly different from each other.

TABLE 4
Median Nutrient Rich Foods (NRF9.3) Index values and food costs calculated per 100 kcal and per serving by selected food subgroups[1]

	NRF9.3/100 kcal	NRF9.3/ serving	$/100 kcal	$/serving	kcal/100 g	NRF9.3 score/$
Milk (n = 12)	39.7	52.7	0.15	0.17	48	318
Yogurt (n = 7)	2.5	36.7	0.34	0.64	85	56
Cheese (n = 24)	5.0	8.1	0.27	0.25	356	37
Milk desserts (n = 26)	−24.5	−13.6	0.15	0.22	210	—
Beef steak (n = 8)	2.2	49.0	0.41	0.90	265	51
Ground beef (n = 4)	−11.1	28.4	0.23	0.52	266	55
Chicken (n = 28)	10.4	39.0	0.30	0.50	213	80
Lunch meats, sausages (n = 48)	−25.2	−15.6	0.21	0.33	306	—
Fish (n = 24)	21.8	46.6	0.49	0.83	186	54
Shellfish (n = 7)	46.9	50.9	1.40	1.61	153	33
Eggs (n = 6)	23.5	15.5	0.12	0.10	160	147
Beans, nuts and seeds (n = 62)	23.1	44.7	0.12	0.17	198	282
White bread, rolls (n = 105)	7.6	17.5	0.12	0.17	292	106
Cakes, cookies, pies (n = 141)	−31.4	−18.5	0.11	0.17	386	—
Crackers and salty snacks (n = 54)	3.3	10.4	0.14	0.18	433	43
Cooked cereals (n = 22)	7.4	41.9	0.08	0.15	100	229
Ready-to-eat cereals (n = 81)	32.3	49.1	0.17	0.22	377	253
Citrus juices (n = 14)	129.5	126.9	0.33	0.30	43	376
Other fruit (mixtures) (n = 333)	47.1	34.0	0.31	0.20	68	138
White potatoes (n = 46)	26.9	38.5	0.12	0.18	130	240
Other vegetables (n = 211)	102.0	42.5	0.57	0.23	47	160

[1] Also provided are NRF9.3 index scores per dollar where NRF9.3 > 0.

eggs, potatoes, and legumes and beans. The present calculations, thus far limited to a small number of food subgroups, illustrate how the econometric approach to nutrient profiling can help identify affordable nutrient-rich foods within and across food groups. This research needs to be extended to finer food subgroups and applied further by using diet optimization techniques to construct affordable healthful diets (34).

Nutrient profiles can also be used to identify healthy, affordable foods across food groups. In 1894, Atwater (13) made a key distinction between cheap and 'economical' foods. In his terms, the cheapest food was that which supplied the most nutrients for the least money. By contrast, the most economical food was the cheapest and at the same time the best adapted to the needs, wants, and resources of the consumer (13). Consistent with those principles, modern consumers select foods on the basis of taste, cost, convenience, and social norms as well as nutritional value (35, 36). Combining nutrient profiling, food prices, and the knowledge of people's food habits can indeed become the platform for offering effective dietary advice to the American public.

The present study brings together some basic concepts that had been explored by Atwater with up-to-date information on nutrition requirements, food composition tables, and food prices. All calculations were based on federal data sets ranging from the USDA nutrient composition and prices data to the FDA serving sizes. Following Atwater's adjustment for calories, calories per unit cost were calculated by dividing calories per serving by the applicable price per serving.

Working with limited nutritional data of his time, Atwater (13) began by calculating the amounts of calories, carbohydrate, protein, and fat in the edible portions of food, which were corrected for refuse and waste, that could be obtained for 25 cents. Rather than consider the weights or package sizes of the foods consumed, Atwater properly focused on the amounts of calories and nutrients per unit cost (13). The science of the time led him to conclude that milk came closest to being the perfect food and that beef and bread together were the essence of a healthful diet (13). By contrast, he worried, in 1894, that the American diet had too little protein and too much starch, fat, and sugar. He described the ratio of nutrient protein to dietary energy or "fuel calories" as unfavorable: in other words, back in 1894, the American diet was already energy rich and protein poor. Protein was the principal nutrient of concern at the time.

In 2005, the Dietary Guidelines Advisory Committee concluded that the American diet was high in energy but relatively low in a number of nutrients of concern, notably vitamins and minerals and fiber (1). Protein is no longer a shortfall nutrient in the US diet. To improve the nutrient-to-calories ratio, consumers were advised to select nutrient-dense foods in preference to discretionary calories. Nutrient-dense foods were described as those that contained relatively more nutrients than calories per reference amount.

In 1894, the foods that provided the most calories per unit cost were starches, sugar, potatoes, beans, and salt pork (13). More than 100 y later, the food groups that provided the most calories per unit cost were grains, sugars and sweets, beans and legumes,

and vegetable fats. However, not all of these food groups provided nutrients as well as calories at a low price and were not, in Atwater's terms, economical. In terms of nutrients per unit cost, as identified by the present scoring system, the highest values were obtained for citrus juices, milk, fortified ready-to-eat cereals, potatoes, and legumes and beans.

Nutrient-profiling techniques can help consumers identify nutrient-rich foods that are integral to the American diet. Being able to assess the nutrient density of individual foods in relation to cost can help consumers identify affordable nutrient-rich foods and make smarter food purchases. However, food rating systems necessarily focus on individual foods without taking meals, menus, or the quality of the total diet into account. Much more work is needed on how different nutrient-profiling systems, which used away from the point-of-sale, can help consumers improve the overall quality of their diets (9, 36). The NRF9.3 system has been positioned within the broader context of dietary education and guidance. More than a food-labeling tool, the NRF index is being applied to studies of affordable nutrition, food preferences, and perceived value for money. We still need to develop appropriate metrics to identify affordable nutrient-rich foods within and across food groups that are part of the mainstream American diet.

The author is Scientific Advisor to the Nutrient Rich Coalition. Coalition members are The Beef Checkoff Program through the National Cattlemen's Beef Association, California Avocado Commission, California Kiwifruit, California Strawberry Commission, Egg Nutrition Center, Florida Department of Citrus, Grain Foods Foundation, National Dairy Council, National Pork Board, United States Potato Board, Wheat Foods Council, and Wild Blueberry Association of North America. No other conflicts were reported.

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