The cost of US foods as related to their nutritive value1–3

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ABSTRACT
Background: Comparisons of the cost of different foods relative to their energy and nutritive value were conducted in the 1800s by the US Department of Agriculture (USDA).
Objective: The objective was to reestablish the relations between food cost, energy, and nutrients by using contemporary nutrient composition and food prices data from the USDA.
Design: The USDA Food and Nutrient Database for Dietary Studies 1.0 (FNDDS 1.0) and the Center for Nutrition Policy and Promotion food prices database were used for analysis. For 1387 foods, key variables were as follows: energy density (kcal/g), serving size (g), unit price ($/100 g), serving price ($/serving), and energy cost ($/kcal). A regression model tested associations between nutrients and unit price ($/100 g). Comparisons between food groups were tested by using one-factor analyses of variance. Relations between energy density and price within food groups were tested by using Spearman’s correlations.

Results: Grains and fats food groups supplied the lowest-cost dietary energy. The energy cost for vegetables was higher than that for any other food group except for fruit. Serving sizes increased with water content and varied inversely with energy density of foods. The highest prices per serving were for meats, poultry, and fish, and the lowest prices per serving were for the fats category. Although carbohydrates, sugar, and fat were associated with lower price per 100 g, protein, fiber, vitamins, and minerals were associated with higher price per 100 g, after adjustment for energy.

Conclusions: Grains and sugars food groups were cheaper than vegetables and fruit per calorie and were cheaper than fruit per serving. These price differentials may help to explain why low-cost, energy-dense foods that are nutrient poor are associated with lower education and incomes. Am J Clin Nutr 2010;92:1181–8.

INTRODUCTION
In comparing the cost of different foods, “we are apt to judge them by the prices per pound, quart or bushel, without much regard to the amounts or kinds of actual nutrients which they contain.” Those words, written by Wilbur Atwater in 1894 (1), still hold true today. Recent articles in the Journal have questioned the use of a calorie adjustment to compare the cost of different foods, arguing instead for the use of prices per package, per 100 g, or per serving (2). One letter writer (3) stated that it was not useful to know that tortilla chips were cheaper per calorie than were fresh strawberries, as long as the 2 packages cost the same, $3.99. The fact that the tortilla chips provided 16 times more energy than did strawberries (4480 compared with 280 kcal) was not viewed as relevant (3).

In 1894, Atwater recognized that different foods varied greatly in the proportion of water they contained (1). Because water contributed to food weight but supplied neither nutrients nor calories, Atwater ignored food weight and calculated instead the amounts of energy and nutrients that could be obtained from different foods for a given price. At the time, corn meal, wheat flour, and sugar provided the most calories for 25 cents (1).

Writing on the nutritive value and cost of food in 1902, Milner (4) had this to say about the cost of fresh produce compared with grains: “Cabbage at 2.5 cents per pound seems cheap, but 10 cents worth of cabbage furnishes 500 calories of energy while 10 cents worth of wheat flour at 3 cents per pound furnishes 5490 calories of energy and is truly cheap” (4). In 2009, an article in the Journal still questioned whether energy-dense grain snacks were really cheaper than fresh produce—on the basis of prices per package and prices per gram (2). Yet, calculations of energy cost, whether expressed as dollars per calorie or calories per dollar, have been around for more than one hundred years.

The 1902 yearbook of the US Department of Agriculture (USDA) even grouped foods according to their energy costs (4). Cheap foods, providing >1900 calories for 10 cents were cereals, sugars, starches, lard, dried beans and peas, cheap cuts of meat, salt pork and bacon, potatoes, and sweet potatoes. By contrast, “expensive” foods that provided <800 calories for 10 cents were lean meats and fish, chicken, eggs, green vegetables, and most fresh fruit. Then as now, grains and sugars were cheaper than fresh produce (4). Far from viewing such information as irrelevant (3), the 1902 USDA yearbook (4) pointed to the many applications that could be made of the knowledge of the relation between cost and the nutritive value of food.

By using more contemporary nutrient composition data sets and food prices from France, Darmon et al (5) confirmed that dry, energy-dense foods provided lower-cost calories than did fresh produce. As confirmed in multiple studies (6–8), fats, grains,
sugar, beans, and potatoes had substantially lower energy costs than did lean meat, fish, lettuce, or fresh fruit (3).

Given suggestions that the low energy cost of grains relative to fresh produce was the result of an autocorrelation (2), it is time to revisit the concept of food prices per calorie compared with prices per bushel. The present research updates the seminal work of Atwater by using USDA nutrient composition and food prices data (9, 10). To counter suggestions that the low cost of energy-dense foods was merely an arithmetic artifact (2), random variables for calculating energy density and energy cost were generated for all foods tested.

METHODS

Nutrient and food prices databases

The nutrient composition database

The USDA Food and Nutrient Database for Dietary Studies 1.0 (FNDDS 1.0) is used to code, process, and analyze the What We Eat in America food intake data (9). 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 (SR) nutrient composition databases (9). The primary description of a given food is linked with a unique 8-digit identification code. The first digit in the code identifies one of the major 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. These food groups will be referred to in text as milk, meat, eggs, beans, grains, fruit, vegetables, fats, and sugars, respectively. The full USDA appellation will be used in the tables and figures. 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. The 9 major food groups created for analytic purposes were based on the first digit of the 8-digit food identification code. As is common in all nutrient composition databases, nutrient values are provided per 100 g of food product, edible portion corrected for preparation and waste.

The food prices database

The Center for Nutrition Policy and Promotion (CNPP) food prices database (10), released in May 2008, was based on information from the 2001–2002 National Health and Nutrition Evaluation Survey (NHANES), the FNDDS 1.0, the National Nutrient Database for Standard Reference (SR 16.1 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. Yield factors were applied to individual ingredients and to the entire dish. This procedure converted foods-as-consumed to foods-as-purchased, with 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 that was listed as consumed at least once in the NHANES database (ie, where frequency of consumption was >1). All foods carried the same 8-digit code as the FNDDS 1.0. Food price measures were unit price ($/100 g), serving price ($/serving), and energy cost ($/kcal).

Food and Drug Administration serving sizes

Common food portions provided in the FNDDS were replaced with US Food and Drug Administration (FDA)—mandated serving sizes—ie, Reference Amounts Customarily Consumed or RACC values (11). The FDA uses 139 different values for serving sizes obtainable from a list of FDA standards. RACC values are set lower for energy-dense sugar (4 g), fats and oils (15 g), and cereals (30 g) than for lower-energy-density meats (85 g), vegetables and fruit (120 g), or soups, fluid milk, and beverages (240 g). By definition then, typical serving sizes are higher for fresh produce than for dry, energy-dense snacks. In the present data set, and depending on food group, the weight of a single serving of food ranged from 1 to 280 g, and calories per serving ranged from 1 to 533 kcal. Serving sizes and water content of foods were inversely linked (Spearman’s correlation coefficient: 0.68). The relation between serving sizes (RACC values) and the energy density of foods is shown in Figure 1.

Exclusion criteria

The present analyses were limited to those foods for which the frequency of consumption in the NHANES database was >5 eating occasions. On the basis of second- and third-digit codes, infant formulas, baby foods, alcohol, and mixed foods were removed. Foods such as human milk, dry flour and biscuit mixes, intense sweeteners and nondairy creamers, chewing gum, and therapeutic formulas including electrolyte solutions and meal replacements were also removed. The database was edited further to remove all duplicate lines, items for which no further specification was provided (eg, “meat, NFS” or “sandwich, NFS”), and other nonspecific items (eg, “vegetable, NS as to type”). To allow calculations of nutrient density and cost per 100 kcal, bottled water (0 kcal) and diet foods and diet beverages with an energy density close to zero (<10 kcal/100 g) were excluded.

FIGURE 1. The relation between serving sizes defined by the US Food and Drug Administration (FDA) [Reference Amounts Customarily Consumed (RACC)] and energy density of foods (kcal/100 g) for 1387 foods in the US Department of Agriculture Food and Nutrient Database for Dietary Studies (FNDDS) (9).
Observational compared with randomly generated data

The observation that energy-dense grains cost more per calorie than does fresh produce was recently called an algebraic artifact (2). The suggestion was that the apparent low cost of energy-dense foods was the result of having calories in the numerator and denominator, and that comparable results could be obtained by using a random-number data set (2). A random-number generator was therefore used to create 3 variables—A, B, and C—for the present study. Each variable had 1387 values drawn independently from a uniform distribution between 1 and 100 to avoid dividing by zero. From these randomly generated variables, 2 ratio variables A/B and C/A were constructed to represent “energy density” (kcal/g) and “energy cost” ($/kcal), respectively, so that observational data could be compared directly with randomly generated results (2).

Statistical analyses

All analyses were performed by using the Statistical Package for the Social Sciences (SPSS) version 11.0 (SPSS Inc, Chicago, IL). Differences in energy density and energy cost across food groups were established by using one-factor analysis of variance (ANOVA) followed by post hoc comparisons between means by using Bonferroni correction. Scatter plots were used to show the relation between energy density and energy cost in the observational data and between the A/B and C/A variables in the randomly generated data set. Additional analyses based on a regression model applied to the observational data examined the relation between nutrient content of foods and unit price ($/100 g) controlled for calories. Those analyses were based on the standard multivariate model proposed by Willett (12), where

\[
\text{Price per 100 g} = b_1 \text{ calories} + b_2 \text{ nutrient}
\]

and \( b \) represent regression coefficient. Within food groups, the relations between energy density and unit price and serving price were examined by using Spearman’s correlation analyses. An \( \alpha \) level of 0.05 was used to determine statistical significance.

RESULTS

Energy density and prices by food group

The characteristics of the 1387 foods, separately for each major food group, are shown in Table 1. The number of different foods in each group is also indicated. Tests across food groups were conducted by using one-factor ANOVA followed by comparisons of means by using the Bonferroni correction. For energy density, the effect of food group was significant [\( F(8, 1378) = 122.1, P < 0.001 \)]. The mean energy density of fats was significantly higher than for all the other food groups except for grains and beans (\( P < 0.001 \)). The mean energy density of grains and beans was significantly higher than for all other food groups except for fats (\( P < 0.001 \)). The mean energy density of sugars was significantly lower than for fats, grains, and beans and significantly higher than for milk, vegetables, and fruit. Milk and eggs did not differ. Vegetables and fruit had significantly lower energy density than did all of the other food groups except for eggs.

For mean water content (g/100 g), the effect of food group was also significant [\( F(8, 1378) = 164.6, P < 0.001 \)]. The water content of grains was significantly lower than that for any other food group. The water content of vegetables and fruit was significantly higher than that for every other food group except for eggs. The water content of beans was significantly higher than that for grains but significantly less than for vegetables and fruit.

Mean serving sizes for fats were significantly lower than those for every other food group except for eggs. Mean serving sizes for fruit were significantly higher than those for every other food

### Table 1

Characteristics of 1387 foods from the Food and Nutrient Database for Dietary Studies and the Center for Nutrition Policy and Promotion food prices database by 9 major USDA food groups as defined by the US Department of Agriculture (USDA)\(^1\)

<table>
<thead>
<tr>
<th>Major USDA food groups</th>
<th>No. of foods</th>
<th>kcal/100 g</th>
<th>g/100 g</th>
<th>Energy density</th>
<th>Water content</th>
<th>Serving size (RACC)</th>
<th>Price per 100 g</th>
<th>Price per serving</th>
<th>Energy cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk and milk products</td>
<td>134</td>
<td>182 ± 112(^a)</td>
<td>66 ± 17(^b)</td>
<td>112 ± 89(^b)</td>
<td>63 ± 53(^d)</td>
<td>0.47 ± 0.33(^b)</td>
<td>0.26 ± 0.15(^a)</td>
<td>0.23 ± 0.13(^a)</td>
<td></td>
</tr>
<tr>
<td>Meat, poultry, and fish</td>
<td>196</td>
<td>224 ± 98(^b)</td>
<td>60 ± 14(^c)</td>
<td>89 ± 51(^c)</td>
<td>0.32 ± 0.16(^b)</td>
<td>0.63 ± 0.38(^b)</td>
<td>0.41 ± 0.31(^b)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eggs</td>
<td>8</td>
<td>171 ± 74(^c)</td>
<td>72 ± 10(^d)</td>
<td>65 ± 28(^e)</td>
<td>0.50 ± 0.47(^e)</td>
<td>0.24 ± 0.21(^c)</td>
<td>0.22 ± 0.14(^b)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry beans, legumes,</td>
<td>62</td>
<td>330 ± 217(^c)</td>
<td>40 ± 33(^d)</td>
<td>76 ± 62(^d)</td>
<td>0.47 ± 0.33(^c)</td>
<td>0.26 ± 0.22(^d)</td>
<td>0.18 ± 0.17(^b)</td>
<td></td>
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<tr>
<td>nuts, and seeds</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grain products</td>
<td>435</td>
<td>337 ± 110(^a)</td>
<td>24 ± 23(^c)</td>
<td>63 ± 53(^d)</td>
<td>0.47 ± 0.33(^b)</td>
<td>0.23 ± 0.20(^c)</td>
<td>0.14 ± 0.10(^b)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fruit</td>
<td>93</td>
<td>67 ± 56(^b)</td>
<td>82 ± 15(^c)</td>
<td>157 ± 75(^e)</td>
<td>0.28 ± 0.22(^b)</td>
<td>0.40 ± 0.33(^d)</td>
<td>0.54 ± 0.48(^b)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetables</td>
<td>257</td>
<td>83 ± 80(^b)</td>
<td>80 ± 11(^b)</td>
<td>102 ± 59(^c)</td>
<td>0.33 ± 0.26(^e)</td>
<td>0.29 ± 0.33(^c)</td>
<td>0.68 ± 0.69(^d)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fats, oils, and salad</td>
<td>51</td>
<td>390 ± 226(^d)</td>
<td>47 ± 23(^d)</td>
<td>22 ± 9(^e)</td>
<td>0.37 ± 0.18(^b)</td>
<td>0.09 ± 0.08(^c)</td>
<td>0.17 ± 0.19(^a)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>dressings</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugars, sweets, and</td>
<td>151</td>
<td>242 ± 190(^b)</td>
<td>45 ± 39(^d)</td>
<td>119 ± 107(^b)</td>
<td>0.40 ± 0.41(^b)</td>
<td>0.23 ± 0.18(^b)</td>
<td>0.22 ± 0.21(^a)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>beverages</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) Data are from references 9 and 10. RACC, Reference Amounts Customarily Consumed. Statistical tests are based on post hoc comparisons after one-factor ANOVA and by using Bonferroni correction. Values with different superscript letters are significantly different from each other.

\(^2\) Mean ± SD (all such values).
Mean serving sizes for grains were significantly different from every other food group except for eggs and beans. There were significant differences across food groups in unit prices per 100 g \(F(8, 1378) = 33.1, P < 0.001\); however, those were not systematically linked to food category. As shown in Table 1, the meat group had the highest mean prices per 100 g ($0.80/100 g), which was significantly higher than that for every other food group. Prices for beans ($0.50/100 g) and grains

**FIGURE 2.** The observed relation between median energy density (kcal/100 g) and median unit cost ($/100 g) for 9 major food groups as defined by the US Department of Agriculture. Total number of foods = 1387.

**FIGURE 3.** The relation between energy density of foods (kcal/100 g) and energy cost ($/100 kcal). Data are means (top panel) and medians (bottom panel) for 9 major food groups as defined by the US Department of Agriculture. Total number of foods = 1387.
($0.47/100 g) were significantly lower than those for meat and significantly higher than those for vegetables and fruit. Prices for vegetables and fruit ($0.32 and $0.28, respectively) were significantly lower than those for meats, grains, and beans. However, the water content of vegetables and fruit was higher and energy density was lower than for the other food groups.

The relation between mean energy density of foods and mean unit cost per 100 g is shown in Figure 2. Meat commanded the highest price per 100 g, which was significantly higher than that for any other food group. For the other food groups, higher prices per 100 g were obtained for the more-energy-dense grains, beans, and fats than for lower-energy-density vegetables and fruit.

There were significant differences across groups in food price per serving \( F(8, 1378) = 49.4, \ P < 0.001 \). Mean prices per serving for meat ($0.63/serving) were significantly higher than those for every other food group. Mean prices per serving for fats ($0.09/serving) were significantly lower than those for every other food group except for eggs. Mean prices for fruit were significantly lower than those for meat but higher than those for every other food group except for vegetables and beans.

Given that a single serving of food could supply from 1 to >500 kcal, meaningful price comparisons across foods or food groups had to adjust for energy. There were significant differences in food price per 100 kcal by food group \( F(8, 1378) = 55.8, \ P < 0.001 \). Energy cost ($/100 kcal) was lowest for grains, fats, eggs, and milk. Energy cost for vegetables was higher than that for every other food group except for fruit. Mean energy cost for vegetables was more than 5 times that of grains and fats and more than double the cost of sugars.

### Energy density and energy cost

Scatter plots that visually depict the relation between energy density of foods (kcal/100 g) and their energy cost ($/100 kcal) in the observational data are shown in Figure 3. The top panel shows group means, and the bottom panel shows group medians. Grains, beans, and fats were associated with higher energy density and lower energy costs. By contrast, vegetables and fruit were associated with lower energy density and higher energy costs. The observed relation was similar to the previously published charts (5–8), which indicated the position of vegetables and fruit relative to grains, fats, and sugars.

The relation between randomly generated variables \( A/B \) ("energy density") and \( C/A \) ("energy cost") is shown in Figure 4. The top panel shows group means, and the bottom panel shows group medians.
group medians. The results were completely random, as might be expected, given that the 3 variables (A, B, C) were randomly generated. The present data contradict the argument (2) that the complex relations in the price hierarchies of the food supply can be replicated by using a random number data set.

The relations between energy density and food price measures were then examined within food groups. As shown in Table 2, on the basis of 1387 foods, energy density was correlated with measures of food price within some food groups. In general, the relation between energy density and food price per 100 g was positive within each food group, whereas the relation between energy density and energy cost was negative. Significant correlations within food group for energy density and energy cost were obtained for meat, fruit, vegetables, fats, and sugars. However, the number of foods within a food group was in some cases inadequate to obtain significant correlations (2). In other cases, both energy density and price structure varied within the defined group. For example, within the milk group, cheese was more expensive per calorie than was fluid milk, whereas within the bean group, some nuts were more expensive than legumes.

**Food cost in relation to nutrient content**

The final analyses dealt with the nutrient content of foods and their cost per 100 g, after adjustment for energy. Adjustment for energy is a standard technique in epidemiologic studies (12). Nutrient-by-nutrient analyses were conducted on those foods in which the amount of the nutrient was >0. As shown in Table 3, polyunsaturated fats (ie, vegetable oils), total fats, carbohydrates (ie, grains), and total and added sugars were significantly associated with lower food costs per 100 g after adjustment for energy. By contrast, protein, calcium, iron, potassium, magnesium, and vitamin C were associated with higher food costs per 100 g after adjustment for energy (13). The present data are

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**TABLE 2**

Spearman’s correlation coefficients between energy density of foods (kcal/100 g) and different price measures based on the Food and Nutrient Database for Dietary Studies (FNDDS 1.0) and the linked Center for Nutrition Policy and Promotion food prices database1

<table>
<thead>
<tr>
<th>Major FNDDS food groups</th>
<th>No. of foods</th>
<th>Unit price</th>
<th>Serving price</th>
<th>Energy cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$/100 g</td>
<td>$/serving</td>
<td>$/100 kcal</td>
</tr>
<tr>
<td>Milk and milk products</td>
<td>134</td>
<td>0.762</td>
<td>−0.03</td>
<td>0.00</td>
</tr>
<tr>
<td>Meat, poultry, and fish</td>
<td>196</td>
<td>0.13</td>
<td>−0.152</td>
<td>−0.562</td>
</tr>
<tr>
<td>Eggs</td>
<td>8</td>
<td>0.48</td>
<td>0.38</td>
<td>−0.33</td>
</tr>
<tr>
<td>Dry beans, legumes, nuts, and seeds</td>
<td>62</td>
<td>0.652</td>
<td>−0.13</td>
<td>−0.25</td>
</tr>
<tr>
<td>Grain products</td>
<td>435</td>
<td>0.492</td>
<td>−0.08</td>
<td>−0.01</td>
</tr>
<tr>
<td>Fruit</td>
<td>93</td>
<td>0.10</td>
<td>−0.09</td>
<td>−0.552</td>
</tr>
<tr>
<td>Vegetables</td>
<td>257</td>
<td>0.00</td>
<td>−0.05</td>
<td>−0.752</td>
</tr>
<tr>
<td>Fats, oils, and salad dressings</td>
<td>51</td>
<td>−0.07</td>
<td>−0.27</td>
<td>−0.722</td>
</tr>
<tr>
<td>Sugars, sweets, and beverages</td>
<td>151</td>
<td>0.792</td>
<td>0.05</td>
<td>−0.432</td>
</tr>
<tr>
<td>Total foods</td>
<td>1387</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

1 Data are from references 9 and 10. Analyses are based on 1387 foods from 9 major food groups as defined by the US Department of Agriculture.

2 $P < 0.05$.

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**TABLE 3**

Results of regression with price per 100 g as a dependent variable and nutrient content and calories as independent variables1

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>No. of foods</th>
<th>Standardized $\beta$</th>
<th>$t$</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total fat</td>
<td>1346</td>
<td>−0.09</td>
<td>−2.37</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Polyunsaturated fat</td>
<td>1338</td>
<td>−0.19</td>
<td>−6.45</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Total carbohydrate</td>
<td>1295</td>
<td>−0.09</td>
<td>−2.81</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>Total sugar</td>
<td>1228</td>
<td>−0.09</td>
<td>−3.34</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Added sugar</td>
<td>688</td>
<td>−0.10</td>
<td>−2.58</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Protein</td>
<td>1353</td>
<td>0.47</td>
<td>19.78</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Calcium</td>
<td>1376</td>
<td>0.12</td>
<td>4.79</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Iron</td>
<td>1367</td>
<td>0.12</td>
<td>4.79</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Potassium</td>
<td>1381</td>
<td>0.23</td>
<td>9.18</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Magnesium</td>
<td>1370</td>
<td>0.17</td>
<td>6.44</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>873</td>
<td>0.07</td>
<td>2.32</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

1 Data are from the Food and Nutrient Database for Dietary Studies (FNDDS 1.0) (9) and the linked Center for Nutrition Policy and Promotion (CNPP) (10) food prices database. Analyses are based on 1387 foods from 9 food groups as defined by the US Department of Agriculture.
consistent with the earlier demonstration that grains, fats and sweets were associated with lower energy costs than were vegetables and fruit.

**DISCUSSION**

The present analyses, based on USDA nutrient composition and food prices data sets, showed that different food groups had different energy costs. ANOVA by food group showed that grains and fats had substantially lower energy costs than did vegetables and fruit. On a per calorie basis, grains, sugars, and fats were cheap, whereas fruit and vegetables were more expensive. These analyses, based on contemporary data sets, replicate analogous results obtained by the USDA in 1894 (1) and again in 1902 (4). Although calculations of energy cost as an appropriate measure of food price have been made by the USDA for the past 100 y, not all nutritionists are convinced of the need to adjust for calories, preferring instead to stay with prices per unit weight (2, 3).

Regression analyses with price per 100 g as the dependent variable further examined the contribution of individual nutrients to food prices. Whereas carbohydrates, fats, and sugars were associated with lower food prices per 100 g, protein, vitamins, and minerals were associated with higher food prices per 100 g, after adjustment for energy. These analyses confirmed that nutrients associated with grains, sugars, and fats were cheaper, whereas vitamins and minerals associated with fruit and vegetables were more expensive.

Water is the main determinant of energy density of foods. Whereas dry grains are energy dense, low-energy-density lettuce is 96% water. As noted above, larger serving sizes (RACC values) were more expensive. Whereas dry grains are energy dense, low-energy-density lettuce provides more “food” (2). Water, which has no nutrients or energy, is not generally recognized as “food.” Atwater himself noted that, although lettuce was a very palatable vegetable, it furnished practically no nutrients of concern (1). Protein was the shortfall nutrient of the time because vitamins had not been discovered.

According to economic historians, there was a political motivation behind linking the nutritive value of foods with their cost. The first generation of nutrition scientists claimed that nutrition could improve the living conditions of the working class, without raising wages, by showing workers how to eat more economically (14–16). The noted historian Harvey Levenstein went even further in suggesting that Atwater wanted to reshape the diets of the working class to avoid social unrest (16). Radical political movements and labor unions of the time blamed free market capitalism for poor diets and worse living conditions (15, 16). The nutritionists of the time focused on making the diets of the working poor more thrifty and more affordable (15, 16).

Arguably, subsidies to commodity crops (wheat, soybeans, corn), as opposed to vegetables and fruit, have led to increasingly cheap calories and a food supply that is energy rich but nutrient poor (16). The current disparity in food prices is not an algebraic artifact but the result of long-established agricultural policies (15, 16). As might be expected, lower-cost calories are preferentially consumed by lower income groups (16).

Within the United States, higher diet quality—often indexed by higher consumption of vegetables and fruit—has been linked to higher education and incomes (17, 18). Studies conducted by the USDA have shown that the poor spend less on food and have more-energy-dense, lower-quality diets (see reference 16). Added sugar consumption, another index of lower cost diets, is highest among lower-income and minority groups (16, 19). Poverty and financial constraints may be one reason for low consumption of fresh produce by the poor and near poor (20, 21).

Ensuring access to affordable healthy foods has recently become a national priority for public health nutrition (22). Claims that the lower energy cost of snacks relative to fresh fruit is a mathematical artifact (2, 3) would imply that all food groups are equally affordable. If fresh fruit and added sugar really cost the same (2), then the current USDA efforts to make healthful foods more affordable to the average consumer could be regarded as misplaced.

The fact that healthful foods cost more than less healthy options is a formidable real-world challenge for nutrition interventions (23, 24). No wonder that many of us would prefer to focus on intricate personal preferences and other psychosocial factors (2). However, the fact is that the distinction between cheap and expensive foods has been made by US nutritionists for a very long time (1, 4). A continuing appreciation of how food costs drive food choices is needed for a more effective food and nutrition policy (25–27).

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**REFERENCES**

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