Current Research

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The Rising Cost of Low-Energy-Density Foods

PABLO MONSIVAIS, PhD, MPH; ADAM DREWNOWSKI, PhD

ABSTRACT
Background Consuming lower-energy-density foods is one recommended strategy for management of body weight. This cross-sectional study used retail food prices to test the hypothesis that low-energy-density foods are not only more costly per kilocalorie, but have increased disproportionately in price as compared to high-energy-density foods.
Design For a list of 372 foods and beverages belonging to a food frequency questionnaire database, retail prices were obtained from major supermarket chains in the Seattle, WA, metropolitan area in 2004 and 2006. Energy density of all items was calculated and prices were expressed as \$/100 g edible portion and as \$/1,000 kcal. Foods were stratified by quintiles of energy density and the differences in energy cost and in percent price change were tested using analyses of variance.
Results High-energy-density foods provided the most dietary energy at least cost. Energy cost of foods in the bottom quintile of energy density, beverages excluded, was \$18.16/1,000 kcal as compared to only \$1.76/1,000 kcal for foods in the top quintile. The 2-year price change for the least energy-dense foods was +19.5%, whereas the price change for the most energy-dense foods was −1.8%.
Conclusion The finding that energy-dense foods are not only the least expensive, but also most resistant to inflation, may help explain why the highest rates of obesity continue to be observed among groups of limited economic means. The sharp price increase for the low-energy-density foods suggests that economic factors may pose a barrier to the adoption of more healthful diets and so limit the impact of dietary guidance.
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P. Monsivais is a research fellow in the Nutritional Sciences Program, School of Public Health and Community Medicine and the Department of Dental Public Health Sciences, School of Dentistry, University of Washington, Seattle. A. Drewnowski is professor and director, Nutritional Sciences Program, School of Public Health and Community Medicine, University of Washington, Seattle.
Address correspondence to: Adam Drewnowski, PhD, Nutritional Sciences Program, School of Public Health and Community Medicine, 305 Raitt Hall, Box 353410, University of Washington, Seattle, WA 98195. E-mail: adamdrew@u.washington.edu

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Substantial evidence from epidemiologic and clinical studies shows that diets high in whole grains, lean meats, low-fat dairy products, and vegetables and fruit are associated with lower risk of obesity and with more favorable health outcomes. Such low-energy-density diets tend to be higher in nutrients per calorie as compared to diets composed of sweets and fats, which tend to be energy-dense but nutrient-poor (1). Energy density, expressed as kcal/g or MJ/kg, is a measure of available energy per unit weight and can be used to describe individual foods (2), menus, or total diets (3). In recent studies, diets of lower energy density were associated with higher dietary quality (1,4,5) and with lower body mass index (calculated as kg/m^2) values in adults (6,7). Lowering the energy density of the diet through consuming more vegetables and fruit is a recommended strategy for management of body weight (8).

However, lower-energy-density diets have been associated with higher energy costs (3). Studies, largely based on data collected outside the United States, suggest that energy-dense foods (9) and energy-dense diets (10) were each associated with lower costs of dietary energy, expressed as €/MJ. Based on food prices in France, sweets and fats provided energy density at a relatively low cost, whereas the energy cost per megajoule of nutrient-rich meats, fish, and fresh produce was considerably higher (11,12). In previous cross-sectional studies of dietary patterns in France, energy density and nutrient density were each independently associated with higher energy costs per megajoule (13).

There are fewer US-based data on the relationship between diet quality, food prices, and diet costs. The importance of this issue is illustrated by a study (14) showing that variations in the prices of fruits and vegetables across major metropolitan markets were sufficient to explain, in part, the observed variations in childhood obesity rates. Studies conducted by the US Department of Agriculture and based on the Consumer Price Index documented that the prices of fresh vegetables and fruit have increased disproportionately between 1985 and 2000 relative to the prices of other food groups, notably fats, sweets, and soft drinks (15).

The present hypothesis was that the widening gap in price between the energy-dense and nutrient-dense foods could be observed locally and over a far shorter period of time. To test the hypothesis, retail prices were collected for the same foods and beverages in the same Seattle supermarkets in 2004 and again in 2006. The monetary cost ($/1,000 kcal) and 2-year price inflation (% change in price) were measured not by food groups but in relation to the food's energy density as explored in past research (1-4,16).

METHODS

The present study used a market-basket approach to assess the prices of foods. A market basket is simply a list of defined products in purchasable form. The same approach is used by the US Bureau of Labor Statistics in monitoring prices and inflation in goods and services as part of the Consumer Price Index. Previous research studies have used the market-basket method to assess the price and availability of food in different geographical areas (17).

Market Basket

The component foods of the food frequency questionnaire (FFQ) instrument developed by the Fred Hutchinson Cancer Research Center represented the market basket used in this study. This FFQ instrument (G-SEL version) constitutes the chief dietary database in many large-scale cohort and cross-sectional studies on diets and health (18,19). The FFQ consists of a list of 126 line-item foods and a set of frequency options. For purposes of nutrient analysis, each of the 126 line items visible to the respondent is represented by between one and four specific foods and beverages that are used to calculate energy content and nutrient composition of each line item. The FFQ is based on a total of 384 unique component foods, excluding medical foods and supplements.

Food Prices

Each FFQ component food was first translated to a specific food item in purchasable form, using a software database of over 27,000 food items. Purchasable items were selected to best match the component food description and had to represent the best value available in terms of cost per unit weight. In most cases, a purchasable form of the specific component food could be identified unambiguously; ie, the description of the component food matched precisely the description of the food selected from the supermarket. In some instances, substitutions were made because the item was unavailable. For example, bluefish is an Atlantic sea fish that was not readily available in Seattle. In its place, a similar sea fish—Pacific red snapper—was substituted. Substitutions were also made when the component food specified a product brand for which lower-cost alternatives were available. For example, many national brand breakfast cereals had nearly identical store brand or "private-label" alternatives that were less expensive. In cases where the component food was a dinner entree or a complete meal, such as tamales with meat or tuna casserole, ready-to-eat or ready-made options were identified in the frozen-food or deli departments. If ready-made options were not available, prices were based on the primary (or most costly) ingredient in the item, eg, extra-lean ground beef in meatloaf, as specified in the FFQ. No suitable matches were found for nine FFQ food items that were primarily mixed dishes from an unspecified recipe. Therefore, these nine items were excluded from the analyses.

Food prices (in US dollars) were obtained from three supermarkets in the Seattle metropolitan area from April to June 2004 and from May to July 2006. Safeway, Albertson's, and Quality Food Centers (a subsidiary of Kroger) together represented over 60% of the retail grocery market in the Puget Sound region in 2003 (20). Prices were obtained during in-store visits and from supermarket Web sites (Safeway, Albertson's), which reported to list the same prices as those available to in-store customers. Some fresh seafood was priced at a major fish market in Seattle and some ready-to-eat foods were priced at local branches of national fast-food restaurants.

For packaged goods, the median package size was typically selected, ie, the package size in the middle of the range offered. For fresh produce, prices were primarily obtained for random weight or "bulk" purchase. The major exceptions were for potatoes, carrots, and some citrus fruits, which are substantially discounted when bought prepacked in bags, and here median sizes were selected. Prices listed were regular prices and did not include discounts that were sometimes offered to loyalty-card holders. When an item was on special, the sale price was ignored and the everyday price was recorded. While prices for fresh produce can vary seasonally, prices were obtained during spring and early summer in 2004 and again in 2006.

For each food, price per 100 g was calculated, taking into account the edible portion or yield. Yield values reflect the gain or loss of food weight that occurs during preparation, because of discarding of nonedible portions (eg, peel or bone) and hydration during cooking (grains and pulses). Yields were obtained from the US Department of Agriculture Handbook 102 (21).

Having established a list of specific purchasable foods for the 2004 database, prices were again obtained for the identical items in 2006. For each specific item (brand, package size), a return visit was made to the same supermarket chain where the product had been priced in 2004. If the product was no longer available at the same chain, the other two chains were searched and the lowest price available for the identical product was selected. In rare cases, the 2004 product had either been discontinued by the manufacturer or had been modified in package size. When this was the case, the item specified in 2004 was replaced with an alternative product that closely matched the original food description. Of the 372 foods for which both nutrient data and prices were available, 309 (83%) were exact same product, same store matches and the remainder were close matches.

Energy Density

Calculations of energy density for 372 foods were based on energy and nutrient values provided by Food Processor version 8.7.0, a dietary analyses software package

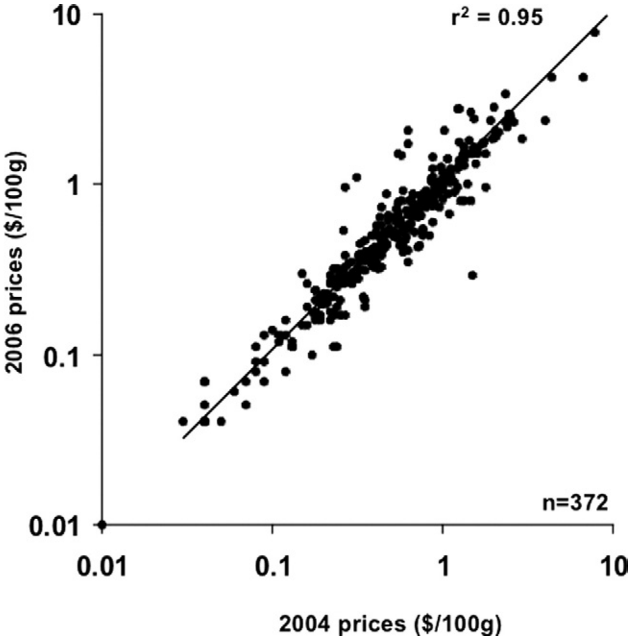

Figure 1. Relationship between retail prices of 372 foods and beverages collected in Seattle-area supermarkets in 2004 and 2006. Seattle-area prices collected in 2006 were strongly correlated with 2004 prices. The overall correlation (r^2) between 2004 and 2006 prices was 0.95.

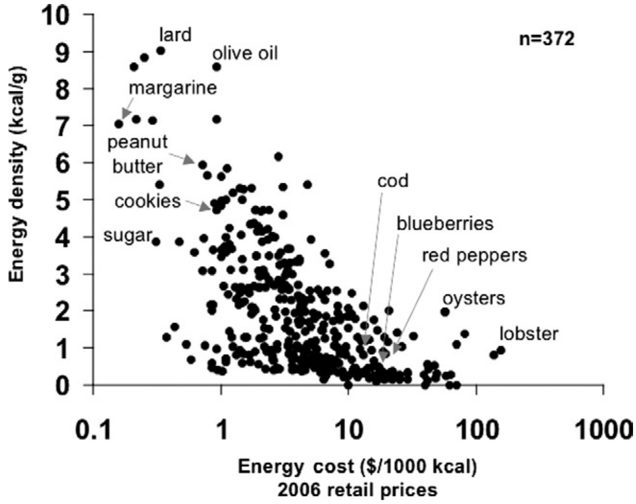

Figure 2. Relationship between monetary cost of dietary energy ($/1,000 kcal) and energy density (kcal/g) of 372 foods from Seattle-area supermarkets for which nutrient and energy data were available. Energy cost was inversely associated with energy density. The data were fit by a linear regression: r^2=0.38. Retail prices for 372 foods and beverages were for 2006.

(ESHA Research, Salem OR, 2006) with ESHA Research nutrient database. Because only energy content was recorded per 100 g portion, no foods were excluded because of missing or insufficient nutrient values. Energy and nutrient data were then retrieved for a 100-g portion of each item. Energy density was defined as kcal/g edible portion for each food and caloric beverage. Following past studies (3,9), analyses of energy density were based on foods and beverages (n=372) and on solid foods only (n=341), with caloric and noncaloric beverages excluded.

Statistical Analyses

The agreement between prices in 2004 and 2006 and the strength of the relationship between cost ($/1,000 kcal) and energy density (kcal/g) as continuous variables were each measured by linear regression, and the correlation coefficient (r^2) was recorded. The relationship between cost and energy density quintile was tested using one-way analysis of variance. The food database was analyzed as a complete list containing both caloric and noncaloric beverages and as food only. In either case, the list was stratified into quintiles of energy density and mean price values ($/1,000 kcal) and price change (% change from 2004) were computed for each level. Bonferroni-corrected multiple comparisons were used to identify significantly different pairs in post-hoc analyses. Analyses were conducted using SPSS statistical software (version 11.0.1, 2001, SPSS Inc, Chicago, IL).

RESULTS

Food-price collection methods were highly reliable in the 2 years of the present study. Figure 1 illustrates the relationship between food prices collected ($/100 g) in 2004 and in 2006 for the same 372 foods. There was a strong correlation between 2004 and 2006 prices (r^2=0.95), and the average price increase calculated for all foods and beverages was 7.9%.

Energy Density and Energy Cost

The relationship between energy density (kcal/g) and energy cost ($/1,000 kcal) was examined, based on 2006 prices. The differential in energy cost was substantial, as illustrated by the use of a logarithmic scale (x-axis) to plot energy costs per 1,000 kcal in Figure 2. That figure shows that energy density was strongly and inversely associated with energy cost (linear regression: r^2=0.38). It can be seen that energy-dense grains, fats, and sweets were associated with lower monetary costs, expressed as $ per 1,000 kcal. In contrast, lean meats, low-fat dairy products, and vegetables and fruit were associated with higher monetary costs per 1,000 kcal.

All solid foods, excluding both caloric and noncaloric beverages, were then stratified by quintiles of energy density. One-way analysis of variance of the energy cost showed significant effects of energy density, $F(4, 340)=13.8$, $P<0.001$. Energy costs of foods, edible portion, in the highest quintile of energy density (range=3.39 to 9.0 kcal/g) were an average of $1.76/1,000 kcal, whereas energy costs for foods in the lowest quintile of energy density (range=0.14 to 0.64 kcal/g) were an average of $18.16/1,000 kcal. Post hoc analyses using the Bonferroni correction showed that the cost of least energy-dense foods was significantly greater than foods in the lowest four quintiles. The same relationship held when beverages, caloric and noncaloric, were included in analyses, $F(4, 371)=12.39$, $P<0.001$.

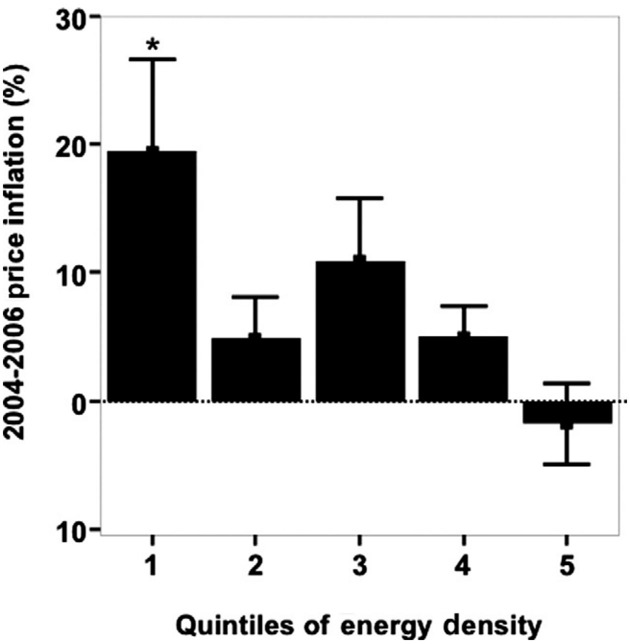

Figure 3. Mean 2-year inflation rate by energy-density quintile for 341 foods (31 caloric and noncaloric beverages excluded). Low-energy-density foods showed the highest 2-year inflation rate. Inflation rate was highest for the low-energy-density group at 19.5% compared to −1.8% for the high-energy-density group. *$P<0.05$ compared to high-energy-density group.

Food Price Increases by Energy Density

The present hypothesis was that lower-energy-density foods would show a disproportionately higher increase in price over the 2-year period. Figure 3 shows the mean 2-year inflation (% change in 2004 price) for 341 foods (beverages excluded) grouped into quintiles of energy density. Foods in the lowest quintile of energy density showed, on average, a 19.5% increase in prices. Foods in the highest quintile of energy density showed, on average, a 1.8% drop in absolute prices over the 2-year period. With the exception of the second-lowest quintile, the inflationary trend was progressively lower for higher levels of energy density. Notably, the second-lowest quintile was unique in that canned foods were highly represented. Of the 67 foods in this quintile, 21 items were canned foods (30% of foods in this group). These canned items are low in energy density and included vegetables, fruits, and soups. Analysis of variance showed a significant effect of energy density on the magnitude of price change, $F(4, 340)=3.14$, $P<0.05$. Post hoc analyses revealed that the effect was a result of the differential increase in price between the highest and lowest quintiles of energy density. The same trend persisted when beverages were included in analysis. There was a significant difference in price increases by energy density quintile [$F(4, 371)=4.48$, $P<0.005$], with the effects a result of a significant difference between inflation rates of the bottom and top quintiles.

Representative foods from the bottom and top quintiles of energy density are shown in the Table, arranged in ascending and descending order of energy density, respectively. The bottom quintile contained foods ranging in energy density from 0.14 to 0.64 kcal/g. The top quintile ranged from 3.39 to 9.0 kcal/g. It can be seen that the lowest energy−density foods were the recommended vegetables and fruit, including fresh fruit and fresh produce. Among foods in the highest quintile of energy density were fats and sweets (lard, sugar), candies, pastries and other baked goods, and snacks. Whereas the lowest energy density quintile was made up primarily of fruits and vegetables, the highest quintile was more diverse, including fats, sugars, grains, nuts, and meats.

DISCUSSION

Improving the nutrients-to-energy ratio in the American diet is the stated goal of the 2005 *Dietary Guidelines for Americans* and the 2005 US Department of Agriculture's *MyPyramid* (22,23). Many studies have provided ample evidence to justify the adoption of lower-energy-density but high-quality diets (6,7), whether for the purpose of weight management (8) or the prevention of chronic disease (24,25). Few of those studies have addressed the issue of food prices and diet costs (16).

Being able to replace fats, sweets, and snacks with less energy-dense options is becoming an ever greater economic challenge (12,26). Previous studies have shown that, using nutrient composition data and national food prices in France, energy-dense foods provided dietary energy at a relatively low cost (27). In contrast, the more nutrient-dense foods were likely to cost more (1,27).

These findings, now based on Seattle prices, clearly show that the price of low-energy-density nutrient-dense foods, largely vegetables and fruit, has outpaced inflation, whereas energy-dense sweets and fats have held their price. These data, collected over only 2 years, are consistent with longer-term analyses of price increases by food groups conducted by the US Department of Agriculture (15). In the present study, the 2-year inflation observed for food overall, 7.9%, was higher than the inflation rate for food at home reported by the Bureau of Labor Statistics' Consumer Price Index) over a similar period (28). The Consumer Price Index reported a 5.1% increase in the cost of food at home between June 2004 and July 2006 for the Seattle-Tacoma-Bremerton Metropolitan Statistical Area. However, it is emphasized that measures reported here are not directly comparable to those from the Consumer Price Index, because they are based on different market baskets.

Prior studies on the economic antecedents of obesity have emphasized the lower cost of food and higher cost of physical activity (29-31). However, it is now clear that not all foods have become uniformly cheaper. Whereas energy-dense foods remain the most affordable option, the price of the recommended healthful foods of lower energy density has disproportionately increased. While earlier studies examined changing food prices by food group (15,32), the present analysis is the first to provide vital evidence that it is the foods of lowest energy density (excluding beverages) that are showing the most marked increases in price.

LIMITATIONS OF THE PRESENT STUDY

The present analyses were based on prices collected from only three major supermarket chains in a single, major

Table. Twenty foods in the lowest and highest quintile of energy density

Lowest ED[a] Quintile (0.14-0.64 kcal/g)		Highest ED Quintile (3.39-9.0 kcal/g)	
ED (kcal/g)	**Food**	**ED (kcal/g)**	**Food**
0.14	Iceberg lettuce head, fresh	9.00	Lard
0.15	Mustard greens, cooked, drained	8.57	Pure vegetable/canola oil
0.16	Zucchini squash, fresh	8.57	Extra virgin olive oil
0.17	Romaine lettuce, fresh	7.17	Salted butter
0.18	Cherry tomatoes, fresh	7.14	Real mayonnaise
0.18	Tomato salsa	7.05	80% Fat margarine
0.19	Cauliflower, cooked, drained	6.15	Oil-roasted mixed nuts w/o peanuts
0.19	Sauerkraut, cooked, drained	5.94	Peanut butter
0.20	Green bell peppers, fresh	5.85	Dry-roasted peanuts
0.22	Cabbage, shredded, cooked, drained	5.67	Hulled sunflower seeds
0.23	Spinach, cooked, drained	5.64	Cheese puffs
0.27	Red bell pepper, fresh	5.41	Popcorn, oil-popped
0.28	Broccoli, cooked, drained	5.41	Cured pork bacon, cooked
0.28	Snap green beans cooked, drained	5.35	Milk chocolate candy bar
0.29	Watermelon, fresh	5.33	Butter crackers
0.29	Wax beans	5.32	Chocolate chips cookies w/nuts
0.30	Jalapeno peppers, fresh	5.29	Potato chips
0.32	Strawberries, fresh	4.98	Tortilla chips
0.32	Green onions bulb and tops, fresh	4.90	Granola
0.34	Cantaloupe melon, fresh	4.73	Wheat crackers-thin square

[a]ED=energy density.

US metropolitan area, and thus cannot account for geographic variation in prices or in inflationary trends (33). In addition, each food and beverage was priced using methods that did not take into account sale prices, loyalty-card discounts, coupons, or other shopping strategies that can help consumers control food expenditures (34). Moreover, the particular group of foods or "market basket" that was evaluated for this study originated from an FFQ, and thus was limited in its representation of many foods that are commonly consumed (35). Consequently, prices and inflation rates reported here might not be representative of the prices experienced by particular consumer groups.

CONCLUSIONS

The sharp price increase observed for vegetables and fruit relative to fats and sweets suggests that the ability to adopt more-healthful diets may be limited by economic constraints. Although low-energy-density foods are undoubtedly associated with better health outcomes, they are also more costly (9,36) and tend to be purchased by the more-affluent consumer (37). The energy density of the American diet is reported to have risen (38), suggesting that the consumer is seeking out lower-cost foods. The finding that energy-dense foods are not only the least expensive, but also most resistant to inflation, may also help explain why the highest rates of obesity continue to be observed among groups of limited economic means.

Health-promotion strategies focused on individual behavior (39) may need to be supplemented with environmental and policy measures to assure equal access to affordable nutrient-dense foods. The 2007 Farm Bill, currently before Congress, may offer one such opportunity, because this piece of legislation shapes the US food supply by determining the subsidies and other payments to food producers (40). The pending legislation contains provisions for making fruits and vegetables more easily available (41). While responsible policy measures are essential to improving the availability and reducing costs of more-healthful foods, the role of food and nutrition professionals has never been more important. Research shows that vegetables and fruits vary substantially in their nutritional value and cost (27). Food and nutrition professionals can play a vital role in guiding consumers to select foods that provide optimal nutrition at affordable prices.

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