



# Identifying Smart Food Choices on the Path to Healthier Diets

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## EXECUTIVE SUMMARY

Most Americans are overfed and undernourished. Typical American diets are chipping away at our public health. The declining quality of the American diet is why the just-born generation is projected to be the first with a lifespan shorter than its parents.

Despite abundance, exceptionally broad choices, and a revival of food culture and culinary skills, we are a nation deeply troubled by food. Indeed, just about everything about it – where and how it is grown; the costs, benefits, and risks of biotechnology versus organic farming; what food manufacturers do to nutrient-rich, whole foods; the impacts of added fat, salt, and sugars; the absence of unique flavors and textures, and how farm animals (and farm workers) are treated.

Slowing the spread and progression of degenerative disease is now high on the agenda of millions of Americans. Almost everyone understands that smart food choices are an essential step toward healthier life. But what exactly is a “smart” food choice?

How does a person lacking a nutrition degree decide whether to consume another serving of a fruit or vegetable, or a grain-based product, or some other food? Most of us have a general sense of which foods are high in specific nutrients, but very few of us have thought through the complex tradeoffs across nutrients when one food is chosen over another. For this task, new tools are badly needed.

And if a person decides to add a serving of fruit, which fruit will deliver the biggest nutrient dividend for the calories consumed? Or, for families on a tight budget or for individuals choosing foods for a school lunch program or extended care facility, which foods deliver the most nutrients per dollar spent?

People have heard over and over that, in the world of nutrition, “one size does not fit all,” and so they wonder how their age, size, level of activity, and health status impacts the nutrients their bodies need, and hence their personal, “smart” food choices.

There is a healthy, overdo debate underway around the world over the surest path forward in lessening the adverse impacts of farming on the environment, while also improving productivity, food safety, and food nutritional quality. Deeply worrisome public health trends driven by poor dietary patterns heighten the importance – and urgency – of this debate over the future of food.

Hard data is badly needed. Particularly, on how different farming systems and technology alter the nutritional quality of food, and indirectly, the health of the people consuming it. Will genetically engineered Golden Rice or organically grown carrots and squash most cost-effectively provide the



vitamin A needed by hundreds of millions of children around the world? How can farmers maximize the human-nutrition units produced per acre or hectare, as opposed to crop yields per unit of land?

### A NEW RULER FOR IDENTIFYING SMART FOOD CHOICES

A smart food choice is one that delivers significant quantities of health-promoting nutrients at a relatively low caloric cost, and without a lot of baggage that can erode health (e.g., added sugar, salt or saturated fat, pesticide or animal drug residues, or artificial food additives).



In this report, we describe a new tool designed to help identify smart food choices from the perspective of nutrient content or nutrient density. Several such nutrient profiling systems have been developed and are currently in use (see section IV for an overview). Each of the systems currently in use has strengths and limitations. We drew on the strengths of existing systems and developed methods to overcome limitations in the course of creating “The Organic Center Nutritional Quality Index” (TOC-NQI).

TOC-NQI is more comprehensive, data-driven, and flexible than any existing nutrient profiling system. It encompasses 27 nutrients: eleven vitamins, eight minerals, protein, fiber, antioxidant activity as measured by total ORAC, lutein + zeaxanthin, linoleic acid, linolenic acid, lycopene, and choline.

A food’s TOC-NQI value is the sum of that food’s contribution to daily nutrient needs across the above 27 nutrients. The food’s share of a given nutrient, say vitamin C, is a simple ratio – the amount of vitamin C in the food, divided by the amount of vitamin C the person should ingest in a day to promote health.

The system is designed to rank food nutritional quality per serving, per calorie, or per gram. It can be modified to estimate nutritional quality for people with unique health and nutritional needs. Unlike other systems, the weights assigned to specific nutrients reflect their relative abundance or inadequacy in typical diets, as well as their importance in promoting good health.

We can generate TOC-NQI values for single ingredient foods (tomatoes versus an apple), multi-ingredient foods (pepperoni pizza, a Big Mac), meals, and even daily diets.

Our research has shown that farming systems, plant genetics, and yield goals can, and typically do, alter nutrient density, hence changing a food’s inherent nutritional quality. We include in our new system a method to adjust TOC-NQI values for the impacts of farming systems, technology, and production levels on food nutrient density.

## “NUTRITION UNITS”

TOC-NQI values are scaled so that a hypothetical daily diet that supplies exactly the recommended amounts of all 27 nutrients—no more, no less of each one—will have a TOC-NQI of 1, or one “nutrition unit.” (In practice, we should aim for more than one nutrition unit per day, because of inevitable, and often substantial, deviations from the hypothetical, uniform distribution of 27 nutrients at exactly recommended amounts.)

TOC-NQI values can be calculated for any quantity of food, but like most nutrient profiling systems, ours ranks foods according to equal, 100-gram portions, 100-calorie portions, or typical servings. It is easy to translate TOC-NQIs based on grams or calories to values based on serving sizes, and vice versa.

Fresh vegetables deliver the greatest nutrient bang per calorie. A 100-calorie portion of common vegetables delivers an average TOC-NQI of 0.25, or 0.25 “nutrition units.” So, very roughly speaking, and ignoring the lack of vitamins B12 and D in vegetables, if the 27 nutrients embedded in TOC-NQI were distributed across four different vegetables such that none were in excess of needs, just these four 100-calorie portions of vegetables might approach adequate amounts of the 27 nutrients needed by a person in a given day, and at a modest caloric cost. The four portions would account for 400 calories, leaving around 1,800 calories to meet other needs and preferences. Note: One-half-cup servings of vegetables generally contain only 10 to 50 calories, so 100-calorie portions are often large, and usually amount to 2 to 10 servings, or 1 to 5 cups.

**Vegetables deliver by far the most nutrients per calorie of all the major food groups**

Fruits deliver, on average, a TOC-NQI of 0.10 nutrition units per 100 calories, with strawberries at 0.22 nutrition units topping the list of the 10 most widely consumed fruits. Whole grains deliver around 0.055 nutrition units per 100 calories, compared to about 0.035 in refined grain breads. But cereals

with added nutrients score higher at around 0.090 if refined and 0.130 if whole-grain, because several nutrients are added to fortify the nutritional content of the products.

Dairy products deliver 0.057 nutrition units on average per 100 calories, while meat and sea foods average about 0.090 per 100 calories.

Based on typical servings (instead of 100 calorie portions), the ranking of food categories is very different, based on group averages:

- ◆ Meats and sea foods – 0.145 nutrition units, average 174 calories per serving
- ◆ Whole grain cereals – 0.13 (enhanced by fortification), average 87 calories per serving
- ◆ Refined grain cereals – 0.10 (enhanced by fortification), average 107 calories per serving
- ◆ Fruits – 0.064, average 75 calories per serving

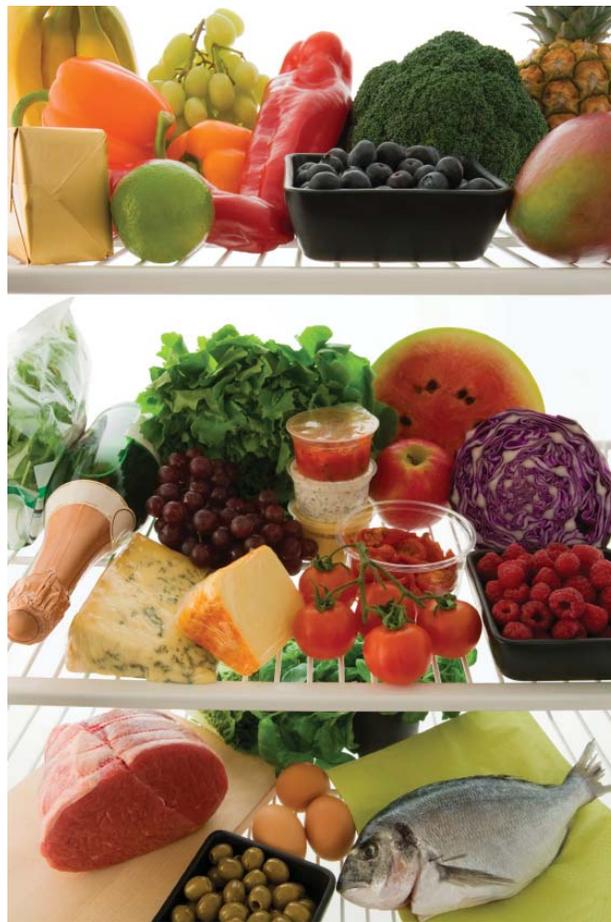


- ◆ Dairy foods – 0.057, average 105 calories per serving
- ◆ Whole grains – 0.054, average 100 calories per serving
- ◆ Vegetables – 0.042, average 29 calories per serving
- ◆ Refined grain breads – 0.024, average 70 calories per serving

The best way to improve most American diets is to choose fewer foods with low TOC-NQI values per 100 calories and more foods with higher TOC-NQI values per 100 calories. Valuable examples are fruits, vegetables, whole grains, and whole food sources of fat such as nuts, whole dairy foods, whole soy foods, avocado, and salmon.

Of course, many factors drive food choices in addition to nutrient content – among them taste, cost, convenience, and availability. But a tool like our TOC-NQI can provide consumers a practical way to narrow food choices to those that make nutritional sense, while meeting other needs.

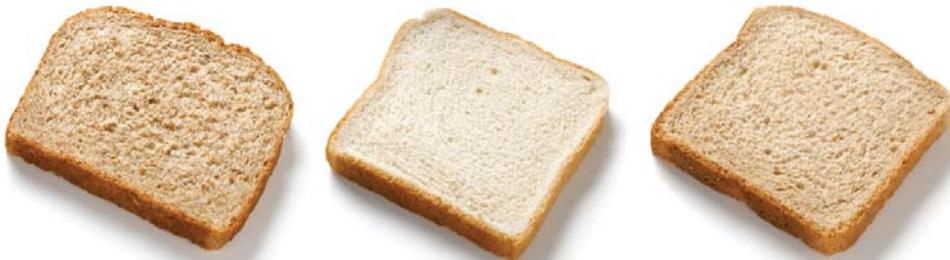
For each and every one of us, smart food choices stand out as the most accessible and affordable way to tilt the odds in favor of good health. TOC-NQI is a powerful, new, and accessible nutrient profiling system, developed in the hope that it will incrementally improve our individual and collective food IQs, so that over time smart food choices become our typical food choices.



## I. INTRODUCING THE ORGANIC CENTER'S "NUTRITIONAL QUALITY INDEX"

The Organic Center's "Nutritional Quality Index" (TOC-NQI) provides a broad-based measure of the nutritional benefits of individual foods, meals, and daily diets. It is designed to help analyze and improve food choices, and thus the nutritional quality of diets for individuals or groups of people of varying age, sex, health status, and dietary preferences. One major use of the TOC-NQI is to help weight-watchers identify foods with the most "bang for the calorie." Our initial focus has been on calculating TOC-NQI values based on the recommended daily nutrient intakes for normal, healthy Americans.

The TOC-NQI for a given food is based on its content of 27 nutrients, encompassing minerals, vitamins, antioxidants, protein, fatty acids, and fiber. Individual nutrients are weighted according to their abundance or shortage in American diets, placing greater emphasis on those nutrients typically falling short in contemporary American diets.



The TOC-NQI allows comparisons of the relative nutritional value of different foods and different food groups. TOC-NQIs for organic foods can be calculated when adequate nutrient content data is available to estimate typical percentage differences in nutrient levels in conventional versus organic foods. The impact of food processing or cooking method directly affects the TOC-NQIs. Combination TOC-NQIs can be calculated for meals and daily diets.

Special-purpose TOC-NQIs can be calculated for individuals or population groups with nutritional needs that differ from normal, healthy persons. In this methodology report, we focus our examples on TOC-NQIs for women of age 19 to 30. These values have been calculated based on the recommended intakes for women in this age group. TOC-NQIs for men in the same age bracket will differ for two reasons: differences in recommended intakes applicable to them, and second, differences in typical nutrient intake levels between men and women. Both differences lead to different weights being applied to a given nutrient in the calculation of TOC-NQIs (details are shown in the Appendix).

For example, the TOC-NQI per 100 grams for boiled potato is 0.037 for men and 0.044 for women of the same age (19 to 30). Among the 27 nutrients in the TOC-NQI, the weighting factor for iron is only about 30% as great for men as for women, and the weighting factors for three other nutrients differ by 33% or more, two of them higher for men (fiber and linolenic acid) and one lower (lycopene). The magnitude of these differences reinforce the need for flexibility in the application of nutrient profiling systems to specific population groups or individuals.

Nearly all of our nutrient content data comes from the U.S. Department of Agriculture's "National Nutrient Database for Standard Reference" (USDA-ARS, 2010). In special situations, we also use industry or published research data (e.g., ORAC, 2010). For recommended nutrient intakes, we use the Recommended Dietary Allowances (RDAs) of the Food and Nutrition Board of the Institute of Medicine, or the Board's estimated "Adequate Intakes" (AIs) for a few nutrients with no RDA. Data on dietary intakes comes from large, nationally representative surveys conducted by the U.S. Department of Agriculture (USDA) and the U.S. Department of Health and Human Services (USDA and HHS, 2007).

In the following sections, we describe the core components of the TOC-NQI, the different ways the TOC-NQIs can be expressed, and details on the calculation of the TOC-NQI. The last section describes other, similar nutrient profiling systems, noting shared elements and differences, and their strengths and weaknesses.

The Organic Center developed the TOC-NQI because no existing, "open source" system meets the analytical needs of the Center. By "open source" system, we mean a transparent, fully documented system that is not proprietary and subject to licensing agreements and fees to obtain access to the details of the equations and data used.

#### A. USDA'S NATIONAL NUTRIENT DATABASE FOR STANDARD REFERENCE

The USDA's online nutrient database is considered the most reliable, extensive and up-to-date source of nutrient content data for foods consumed in the U.S. For the most common foods, USDA begins with many samples of each food, purchased from a nationally representative sample of retail stores. For other foods it may obtain only one or a few samples.

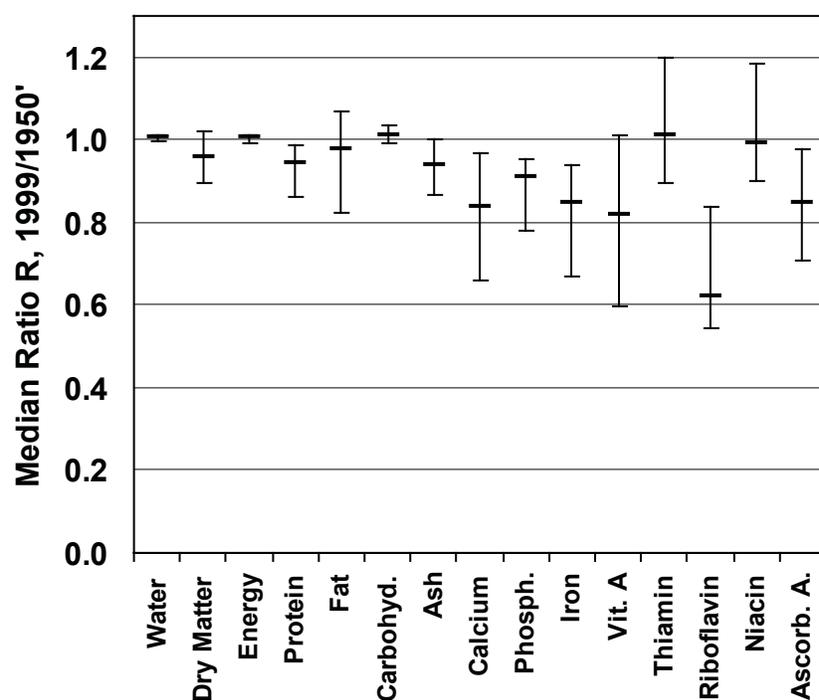
USDA technicians analyze these samples for dozens of nutrients and other components, and report for each one the mean content, the "standard error" of the mean (a measure of its statistical uncertainty), and the number of samples analyzed. The USDA updates parts of its database every year or two, but individual foods typically are updated only every 10 years or so.

The USDA does not currently report nutrient contents for organically grown foods, no doubt partly because of the common belief that there are no reliable, consistent nutritional differences to measure. However, in recent years a growing body of evidence demonstrates significant nutritional benefits stemming from organic cultivation for some nutrients, particularly for phytochemicals, including lutein, lycopene, and measures of antioxidant capacity such as ORAC (Oxygen Radical Absorbance Capacity; ORAC, 2010). The Organic Center actively sponsors and collects such studies (Benbrook et al., 2008; Benbrook, 2005), and hopes that its TOC-NQIs will help place into sharper perspective the typical nutritional advantages of organically grown foods.

Recent studies of USDA's historical nutrient content data, as well as other studies over many decades, show clear downtrends of some nutrients in wheat, other grains, groups of vegetables, and some fruits (Davis, et al., 2004; Fan, et al. 2008; Davis, 2009).

Figure 1.1 provides a summary of median changes in nutrient concentrations between 1950 and 1999 in 43 common fruits and vegetables.

Note the significant reductions in protein, calcium, phosphorus, iron, riboflavin, ascorbic acid, and probably vitamin A. According to the USDA report, "What We Eat In America, 2001-2002," 44% and 31% of the U.S. population consumed less than the estimated average needs for vitamins A and C, respectively, and 5% failed to meet the same standard for phosphorus and iron (USDA and HHS, 2007). Among nutrients without historical data from 1950, 12% to 56% of Americans were below applicable RDAs for magnesium, vitamin B6, and zinc. Clearly, incremental reductions in the levels of some nutrients over the last five decades has created or worsened gaps in nutrient intakes.



**Figure 1.1.** Median ratios of nutrient concentrations per dry weight, 1999/1950. Ratios below 1 represent declines since 1950. Vertical bars show the "95% confidence limits" of statistical uncertainty (Davis, et al., 2004).

Nutrient declines in vegetables, fruits, and grains are apparently caused mostly by the well-known "dilution effect," triggered by increasing yields (increasing harvests per acre). The physiological and genetic sources of the dilution effect are discussed in detail in the Center's Critical Issue Report entitled, "Still No Free Lunch: Nutrient levels in the U.S. food supply eroded in pursuit of higher yields" by Brian Halweil.

Another cause of nutrient declines is changes in the physical form of some crops, for example the short-straw (dwarf) wheat and rice varieties of the Green Revolution. Yields of these crops have strongly increased over the last 50 years or more, achieved by a combination of selective breeding, hybridization, and intensive farming methods. We look forward to obtaining nutrient content data and calculating TOC-NQIs for older, "heirloom" varieties and for crops grown under conditions that emphasize nutritional quality more than high yield.

We are also compiling a dataset on the nutrient content of indigenous fruits and vegetables in Asia, Africa, and South America, for purposes of calculating TOC-NQIs. These values will then be used in conjunction with typical crop yields per acre or hectare to estimate the “human nutrition units” harvested per acre/hectare devoted to alternative crops, and to compare modern versus traditional varieties.

#### B. RECOMMENDED DIETARY ALLOWANCES (RDAs) AND ADEQUATE INTAKES (AIs)

RDAs are based on the Food and Nutrition Board’s estimates of the average nutrient requirements of “normal, healthy” persons, plus an additional amount, commonly 30%, intended to accommodate individual differences in nutrient needs. Thus, RDAs are intended to meet the requirements of nearly all normal, healthy persons, including those with above-average needs.

Although not everyone needs the full RDA of each nutrient, there is generally no way to predict who has greater than average needs of any specific nutrient. Moreover, no harm arises from intakes moderately exceeding actual requirements. As a result, the RDAs serve as recommended daily intakes for everyone. “Adequate Intakes,” or AIs, are preliminary recommendations for nutrients for which there are insufficient data, or lack of consensus, on the basis to establish an RDA.

RDAs and AIs change over time, as new knowledge accumulates about nutrient functions and needs. For example, AIs for calcium and vitamin D were upgraded in late 2010 to RDAs, with minor changes for calcium and large increases for vitamin D. In turn, these changes affect the TOC-NQIs for foods containing these nutrients.

#### WHAT DOES ADEQUATE INTAKE MEAN?

There is another way to think about RDAs, AIs, Daily Values (DVs), and other measures of adequate intake for a given nutrient. People consuming a given nutrient at the RDA, AI, or DV level are not likely to gain any additional health benefits from intakes above those levels, unless of course they have heightened needs, or other special circumstance applies.

There are no official government RDAs/AIs, or DVs for the phytochemicals lutein, zeaxanthin, and lycopene, or for measures of antioxidant capacity such as ORAC. To include these items in the TOC-NQIs, we estimated AIs based on intakes in recommended diets and/or emerging evidence on the health benefits of these substances, including epidemiological studies exploring the impacts of various intake levels on human health.

Lutein and zeaxanthin are important, but little-known, carotenoids with significant antioxidant capacity. Both concentrate in our eyes and seem to help protect them from damage by light. Foods such as spinach, other greens, and yellow corn are good sources of these yellow-orange pigments. They are chemically so similar to each other that many analytical methods do not distinguish between them. For this reason, the levels of lutein and zeaxanthin in foods are usually reported together as a sum.

Based on published research, we have set an adult “AI” for lutein + zeaxanthin of 2,000 micrograms per day. Typical daily intakes in the U.S. range from less than 1,000 micrograms to over 5,000 micrograms. The popular multi-vitamin Centrum Silver contains 250 micrograms of lutein +

zeaxanthin, while some stand-alone lutein + zeaxanthin supplements contain as much as 6,000 micrograms.

Lycopene is another antioxidant and carotenoid pigment. It gives the red color to ripe tomato and watermelon. It accumulates in the liver and other organs, and is being studied for possible roles in helping prevent prostate, lung and other cancers. Tomatoes, and especially cooked tomato products, are the major sources for most Americans. The few other significant sources of lycopene are watermelon, papaya, red-fleshed guava, and pink grapefruit. Our "AI" of 10,000 micrograms per day is based on average U.S. intakes ranging from 5,000 to over 15,000 micrograms per day in various groups. A cup of stewed tomatoes contains 10,000 micrograms of lycopene, and a cup of watermelon, 7,000 micrograms. The Centrum Silver supplement contains 300 micrograms.



ORAC is a leading measure of antioxidant capacity of foods, now reported by USDA for several hundred foods, mainly fruits and vegetables (ORAC, 2010). Some grains, beans, nuts, milk, spices, and chocolate also show substantial antioxidant activity in the ORAC assay, but much more complete ORAC data is needed for these foods. USDA researchers have estimated a U.S. average daily consumption of 5,700 ORAC units from fruits and vegetables alone, corresponding to about 2.5 servings per day of fruits and vegetables. They noted that the recommended 9 servings per day of fruits and vegetables would supply about 20,000 ORAC units. For TOC-NQI calculations we use a provisional adult "AI" of 20,000 units and a U.S. average consumption of 10,000 ORAC units, including poorly known contributions from grains, beans, nuts, milk, spices, and chocolate.

Eating high-ORAC foods like apples, blueberries and artichokes raises the antioxidant power of human blood, and animal studies suggest that high-ORAC foods may slow aging processes that can impair memory and learning ability. One cup of raw blueberries provides 6,900 ORAC units, and organic blueberries provide even more (about 50% more according to a 2008 report by Wang, et al.). Several common fruits and vegetables provide 1,500 to 7,000 ORAC units per serving, especially dark, intensely colored ones like red grapes, red apples, strawberries, asparagus, and broccoli. However, human benefits from intake of some antioxidants, and their possible mechanisms of action, remain unproven. Researchers hope that ORAC studies will help explain the observed benefits of



fruits, vegetables, and other high-ORAC foods, benefits that seem greater than can be explained by their content of vitamins, minerals and other established nutrients. Some suggest that the benefit of antioxidants may be indirect—not from their antioxidant activity, but from human biochemical processes triggered by these substances. In any case, ORAC assays do not measure the bioavailability of antioxidants in foods, or their stability or activity in the body, and they do not capture the antioxidant activity of all phytochemicals, such as carotenoids.

In an ORAC assay, a food sample is mixed with a fluorescent molecule that is vulnerable to destruction by oxidation. A generator of reactive peroxy radicals is then added to the sample. These radicals slowly oxidize and destroy the fluorescent molecule at a rate that is measured by its declining fluorescence (light emission). However, some antioxidants in the food sample intercept and neutralize the added peroxy radicals, helping to protect the fluorescent molecule from oxidation. Thus a high-ORAC food is one with high activity against peroxy radicals, measured by prolonged survival of the fluorescent “probe” and its light emission.

Beginning about 2003, the fluorescent molecule-of-choice used by analytical chemists has been fluorescein, which gives ORAC values several times larger than earlier measurements using another fluorescent probe that proved unreliable. We use only ORAC values based on fluorescein in the calculation of TOC-NQIs. This is why the ORAC values in this report are about six to seven times higher than the values in TOC’s 2005 report on the impact of organic farming on the levels of antioxidants in food (Benbrook, 2005).

Although there are many antioxidants in foods, ORAC values are believed to measure mainly polyphenols. ORAC assays are insensitive to carotenoids such as beta-carotene, lutein, zeaxanthin, and lycopene. For this reason, we include both ORAC and carotenoids in the TOC-NQI.

### C. DIETARY INTAKES OF NUTRIENTS

For average nutrient intakes in the U.S., we use the “Usual Intakes from Food,” based on the National Health and Nutrition Examination Survey (NHANES) for 2001-2002, a large survey conducted by the USDA and the U.S. Department of Health and Human Services. These average intakes are conveniently shown for the same age and population groups that are used for reporting RDAs and AIs.

For intakes of lycopene and lutein + zeaxanthin, we had to use averages from the NHANES for 2007-2008, using its age and population groups that most closely match the RDAs (e.g., females age 20 to 29 instead of age 19 to 30 for the RDAs). As noted above, for ORAC, we use an estimated average intake of 10,000 units per 2,200 calories (for women age 19 to 30).

### D. APPLYING THE TOC-NQI TO SUBPOPULATIONS WITH UNIQUE NEEDS

The TOC-NQI is designed to accommodate customized applications to populations with special needs, in three primary ways. First, the RDA or AI for a specific nutrient, or set of nutrients, can be adjusted when published research has documented a difference either in the amount of nutrient needed in a day to sustain health, or in the bioavailability of a specific nutrient. For example, a number of GI tract problems can reduce the uptake of certain nutrients, requiring people to increase consumption to avoid sustained deficiencies.

Second, the weights assigned different nutrients can be adjusted. Weights are assigned to specific nutrients in the TOC-NQI reflecting the degree to which a typical diet provides ample supplies of a given nutrient. Increasing the weight assigned to a specific nutrient will enhance the influence of that nutrient in a food's total TOC-NQI value. An individual hoping to combat chronic inflammation and pain, for example, might choose to increase the weight placed on known anti-inflammatory nutrients, such as omega-3 fatty acids and polyphenols in plants that are potent antioxidants.

Third, the TOC-NQIs can measure the impact of dietary choices over the course of a day, if we calculate a composite NQI for all food consumed in a day. This ability to assess daily diets is critical in many instances, such as for individuals on poor diets, or those with restricted diets, where a few foods might consistently account for an unusually large share of daily caloric and nutrient intakes. By applying the TOC-NQI to full diets, it is possible to calculate an objective estimate of diet quality, and to assess whether restricted diets, or a new plant variety or food preparation method, are creating some unanticipated nutrient deficiencies.

An increasing number of Americans are focusing on weight management and prevention of type-2 diabetes. For these people, a premium is placed on foods that deliver a significant share of daily nutritional needs, but at the expense of relatively few calories. By focusing on TOC-NQI values per 100 calories of food, as opposed to a serving, people can quickly identify which foods offer the most "bang for the calorie" in meeting nutritional needs.



## II. ESTIMATING THE NUTRITIONAL QUALITY INDEX OF A SINGLE FOOD

The TOC-NQI value for a single food is based on its content of 27 nutrients—eleven vitamins, eight minerals, protein, fiber, choline, linoleic acid, linolenic acid, lycopene, lutein + zeaxanthin, and total ORAC. The latter three items encompass diverse “phytochemicals” that are valuable for health, even though they are not considered strictly essential nutrients, and thus have no official RDAs or AIs.

Based on our estimate of the importance of these nutrients to the health and quality of life for most Americans, we weight them in the TOC-NQI algorithm using a two-step process. First, we establish the following initial nutrient shares, or weights, that add up to 100%:

- ◆ Eleven vitamins – 2.4% each, total 26%
- ◆ Eight minerals – 2.4% each, total 19%
- ◆ Protein – 16%
- ◆ Fiber – 10%
- ◆ Antioxidant activity as measured by total ORAC – 8%
- ◆ Lutein + zeaxanthin – 5%
- ◆ Linoleic acid – 5%
- ◆ Linolenic acid – 5%
- ◆ Lycopene – 3%
- ◆ Choline – 2.4%

The 11 vitamins include A, D, E, K, B<sub>6</sub>, B<sub>12</sub>, C, folate, thiamin (B<sub>1</sub>), riboflavin (B<sub>2</sub>), and niacin (B<sub>3</sub>).

The eight minerals include calcium (Ca), potassium (K), magnesium (Mg), phosphorus (P), copper (Cu), iron (Fe), selenium (Se), and zinc (Zn).

Initial shares of 2.4% for vitamins and minerals are allotted equally to each of the 11 vitamins and eight minerals. Protein, fiber, and ORAC have larger shares, because they consist of multiple substances, e.g. the nine essential amino acids in protein. Linoleic acid and linolenic acid are precursors for other fatty acids. Lutein, zeaxanthin, and lycopene are important antioxidants not significantly measured by the ORAC assay.



These weightings are subjective estimates with an emphasis on the biologically active compounds found especially in fresh, whole foods. We have placed heightened importance on phytochemicals because of:

- ◆ The many suspected health-promoting properties of antioxidants in food,
- ◆ The emphasis placed on increasing intakes of fresh, whole fruits, vegetables, whole grains, and nuts in the most recent *Dietary Guidelines* from the USDA,
- ◆ The general consensus that antioxidant intakes need to at least double across the population to optimally combat the damage triggered by reactive oxygen and nitrogen species (so-called “free radicals”), and
- ◆ The growing evidence that phytochemical intake may be valuable for slowing aging processes.

Weights assigned to specific nutrients can be changed as new information becomes available or when the TOC-NQI is applied to a sub-population with special nutritional needs.



The second step in establishing final weights for each of the 27 nutrients is driven by their relative abundance or deficiency in typical American diets compared to recommended intakes. In this step, for a given population group, we multiply the share assigned to each nutrient in step one by the inverse of the population group’s average intake compared to their RDA or AI. Our method strives to take into account the relative need for a specific nutrient in a given food, in light of all the other foods typically consumed by people in a given population group.

For example, if the average intake of a given nutrient is only half of the applicable RDA or AI, we increase that nutrient’s weight by  $1/0.5 = 2$ . We call this ratio the “deficiency” of the nutrient, which is, in this example, two. If the average intake is twice the RDA, we decrease that nutrient’s weight by the factor  $1/2 = 0.5$ , a “deficiency” of less than 1 (i.e., a surplus). There is no adjustment if the average intake equals the RDA (deficiency = 1).

Our final “index weights” for the 27 nutrients in the TOC-NQI are these deficiency-adjusted shares, normalized so that the total index weight of all 27 nutrients = 1 for each population group. Details are shown in the Appendix. Because of this normalization step, the TOC-NQI of one day’s food is always 1 under the hypothetical situation that someone consumes exactly the RDA or AI for each of the 27 nutrients. (Under realistic conditions in which some nutrient intakes always exceed the recommended amounts, the TOC-NQI for one day’s food should be greater than 1, perhaps 1.5 to 2.)

The 27 final index weights can change in two situations. One is a change in the initial shares for each nutrient (e.g. protein’s 16% share). If one initial share is increased or decreased, other shares must compensate, so that the total shares remain 100%. These share changes flow through to the index weights for each nutrient. The other cause of changes in index weights is much more common—changes in the recommended intakes or “deficiency” factors (average intakes/recommended intakes). The Appendix shows many examples of such differences in the index weights for women and men of the same age.

In general, all 27 deficiency factors will vary for each population group with distinctive average intakes or distinctive recommended intakes. In either situation, the total of 27 index weights is renormalized to 1, so that TOC-NQIs remain comparable among diverse population groups, and the one-day TOC-NQI remains 1 for someone who consumes exactly the RDA or AI for each nutrient.

For each nutrient and population group, the contribution to the TOC-NQI for an individual food is the index weight for that nutrient times its amount in the food, expressed in RDA units. The TOC-NQI for the food is the sum of these 27 contributions. A detailed example is shown in the Appendix, which presents step-by-step the calculation of three TOC-NQIs for raw spinach (for 100 g, 100 calories and one serving). These three TOC-NQIs differ only in the amount of food used in the last step of the calculation.

#### CALCULATING TOC-NQI VALUES FOR AN INDIVIDUAL

When applying the NQI to the nutritional needs of a given person, two issues arise in determining the appropriate weighting factors to use across the 27-nutrients. The first issue is whether the RDAs and “initial shares” described above may differ for a specific individual, compared to population averages, because of some health condition, medication the person is taking, or perhaps differences in genetics or digestive system health. One way to accommodate such special cases is to adjust the initial shares assigned to specific nutrients, while another option would be to adjust the RDAs. The ability to take into account variability in the health status and nutrient needs of individuals is an advantage of the TOC-NQI system, although knowing how to do so often raises complex questions that scientists cannot yet answer with certainty or clarity.

The second issue is that an individual’s average daily intakes of specific nutrients might differ markedly from their population cohort averages. In such a case, using the cohort average intakes to calculate the “deficiency” weights described above (based on the adequacy/inadequacy of intakes relative to the RDAs/AIs) will skew NQI values. In future versions of the TOC-NQI, we plan to develop methods to address this issue by calculating customized NQI values for individuals based on their own dietary patterns.

This second issue (and how to address it) also applies to the calculation of TOC-NQI values for daily diets (see section III, Applying the TOC-NQI to Combinations of Foods and Daily Diets).

For example, suppose Bob Smith consumes 20% more vitamin C on the average day than needed to meet his RDA, whereas Bob's population cohort consumes, on average, only 80% of the RDA. Our "deficiency" weighting factor increases the weight or importance of vitamin C by 25%, even though on a day-to-day basis Bob is already consuming more than enough vitamin C.

If information is available on an individual's dietary choices over an extended period of time, e.g. one month, a season, or a year, it will be possible to calculate customized "deficiency" weights for each of the 27-nutrients in that time period, which can then be used for calculating individualized NQIs for foods and daily diets.



**Kale scored very high in all nutrient profiling systems because of exceptionally high levels of vitamin K and lutein plus zeaxanthin.**

#### A. DEALING WITH FOODS HAVING EXCEPTIONALLY HIGH LEVELS OF A FEW NUTRIENTS

A few foods have extraordinarily large amounts of certain nutrients, for example, vitamin K in kale. To prevent any one nutrient from contributing excessively to a food's TOC-NQI value, we use a maximum nutrient content cutoff of five RDAs per 100 calories of food. This cutoff was chosen to identify the most extremely disproportionate nutrients. It affected almost exclusively vitamin K and lutein + zeaxanthin in green, leafy vegetables. It also occurred with three nutrients in liver (copper and vitamins A and B<sub>12</sub>). A method to truncate extreme contributions to TOC-NQI values for specific nutrients is also justified biologically, because multi-RDA amounts in a single serving may not be well absorbed nor enhance health.

Spinach is a good example. A one-cup serving of raw spinach (only 7 calories) contains about 1.6 RDAs each of vitamin K and lutein + zeaxanthin (for women age 19 to 30). A person would need to consume over 14 cups of spinach to ingest 100 calories, a quantity of spinach delivering almost 23 times the RDAs for vitamin K and lutein + zeaxanthin.

Without truncation, the spinach TOC-NQI per 100-calorie serving would be 0.181, with 84% of the total coming from these two nutrients alone. But after truncation to a maximum of 5 RDAs per 100

calories, the TOC-NQI per 100-calorie serving drops to 0.059. This reduced value is still larger than the TOC-NQI per 100 calories for most vegetables, and these two nutrients are still the leading contributors to TOC-NQI, but the truncation prevents these two nutrients from producing an extraordinarily large TOC-NQI that excessively discounts the importance of most of the many other nutrients in spinach. Vitamins A, E and C, plus folate, magnesium, fiber, protein, and ORAC each contribute 2.7% to 8.3% to the smaller TOC-NQI for spinach, compared to a reduced, but still major contribution of 50% from vitamin K and lutein + zeaxanthin. Whether and how very high levels of specific nutrients in certain foods are truncated is one important factor that differs markedly across nutrient profiling systems.

#### B. DIFFERENT WAYS TO EXPRESS TOC-NQI VALUES SERVE DIFFERENT PURPOSES

The TOC-NQI value for a given food naturally depends on the amount of food chosen for consideration. In the example above, we mentioned the TOC-NQI value for a typical serving of raw spinach. We will show many more examples of TOC-NQI values for typical single servings of fruits, vegetables, grains, dairy products, meats, and other foods.

Per-serving TOC-NQIs are especially useful for comparing the broad nutrient contribution of two similar foods, whether two different fruits or vegetables, white vs. brown rice, whole vs. skim milk, or—where we have data—organic vs. conventional foods of the same type. One way to improve diets is to choose between similar foods based on their TOC-NQIs per serving—the higher the TOC-NQI per serving, the greater the contribution to a person’s daily nutrient needs.

Because the serving sizes and density of different foods can vary widely, TOC-NQIs per serving are often not very comparable. For example, a half-cup serving of carrots contains 27 calories compared to only 8 calories in a one-cup serving of lettuce. This calorie difference contributes to a large difference in TOC-NQI per serving, 0.07 for carrots and 0.02 for lettuce. But on an equal-calorie basis, the TOC-NQIs are the same for carrot and lettuce, 0.26 per 100 calories. For these kinds of comparison, it is sometimes useful to compare TOC-NQIs for the same number of *calories* of food.

We will illustrate this key point by taking a closer look at some TOC-NQIs calculated for 100-calorie portions of each food. These TOC-NQIs per 100 calories allow the fairest possible comparisons of the broad nutrient contents of different types of food, such as vegetables versus grains or meat or dairy products.

TOC-NQIs per 100 calories are a measure of what nutritionists call “nutrient density,” or nutrients per calorie. TOC-NQIs per 100 calories are generally by far the highest for vegetables and fruits, which reflects the great value of these foods for improving typical American diets. At the other end of the nutrient-density spectrum are refined foods such as purified sugars, refined grains, and added fats and oils.

The low TOC-NQIs per 100 calories of the latter foods show that they pack the least amount of nutrients into their considerable calories. Foods with low TOC-NQI per 100 calories are often referred to using one of two less-than-flattering labels—“junk food” or “empty calories.”

The best way to improve most American diets is to choose fewer types of food with low TOC-NQI values per 100 calories and more foods with markedly higher TOC-NQI values per 100 calories. Especially valuable examples are fruits, vegetables, whole grains, and whole food sources of fat such as nuts, whole dairy foods, whole soy foods, avocado, and salmon.

Finally, TOC-NQI values can also be calculated for a fixed weight of food, e.g. 100 grams. We use TOC-NQIs per 100 grams of food for comparing the “TOC-NQI productivity” of different farms and cropping patterns. TOC-NQIs per 100 grams of food tend to be highest for foods low in moisture, such as dry grains or beans and nuts. But some watery fruits and vegetables are so rich in nutrients that they also have high TOC-NQIs per 100 grams, despite their high water and low calorie contents (for example, parsley and strawberries).

These three different ways to calculate and express TOC-NQIs—per serving, per 100 calories, and per 100 grams—serve different purposes, but are obviously closely related. Any one of the three can be calculated from either of the other two (see “TOC-NQI Calculations for Raw Spinach” in the Appendix). But people need to understand the differences in these three versions of the TOC-NQI, because smart dietary choices will depend on choosing the right TOC-NQI to guide a particular type of decision.

### C. NUTRITIONAL QUALITY INDICES FOR A FEW FOODS

TOP 10 US VEGETABLES BY RETAIL WEIGHT	NUTRITIONAL QUALITY INDEX				
	PER 100 GRAMS	PER 100 CALORIES	PER SERVING	SERVING SIZE	SERVING CALORIES
Potato, boiled in skin & peeled	0.044	0.051	0.034	1/2 cup	68
Onion, boiled	0.030	0.067	0.031	1/2 cup	46
Lettuce, iceberg	0.037	0.262	0.021	1 cup	8
Tomato	0.045	0.250	0.041	1/2 cup	16
Lettuce, Romaine	0.130	0.766	0.061	1 cup	8
Bell pepper, green	0.061	0.303	0.046	1/2 cup	15
Corn, yellow	0.074	0.077	0.056	1/2 cup	72
Carrot, boiled	0.090	0.257	0.070	1/2 cup	27
Cabbage, boiled	0.066	0.286	0.049	1/2 cup	17
Cucumber, with skin	0.018	0.119	0.009	1/2 cup	8
<b>AVERAGE</b>	<b>0.059</b>	<b>0.244</b>	<b>0.042</b>		<b>29</b>

Of all the food groups, vegetables pack the most nutrients into their few calories, shown here by their exceptionally high average TOC-NQI of 0.24 per 100 calories. Typical servings have a TOC-NQI of 0.03 to 0.05, at the expense of only 10 to 50 calories. Unfortunately, less than one in three Americans meets the old, minimal goal of three servings of vegetables per day. The contemporary USDA-recommended intake is four to six daily servings for most adults, depending on an individual’s activity level. A major goal of these recommendations is to help reduce the risk of heart disease, stroke, obesity, and some cancers (USDA’s *Dietary Guidelines for Americans*).

Nutrients that contribute the most to the TOC-NQIs for vegetables include vitamin K, lutein + zeaxanthin (both mainly in green vegetables), fiber, vitamins A and C, and ORAC. (We estimated ORAC values for a small number of fruits and vegetables, based on values for similar foods.) Tomatoes stand out for lycopene. Vegetables also contribute many other vitamins and minerals.

TOP 10 US FRUITS BY RETAIL WEIGHT	NUTRITIONAL QUALITY INDEX				
	PER 100 GRAMS	PER 100 CALORIES	PER SERVING	SERVING SIZE	SERVING CALORIES
Banana	0.042	0.047	0.049	Medium	105
Apple	0.043	0.083	0.055	Medium	67
Watermelon	0.036	0.119	0.054	1 cup	46
Cantaloupe	0.036	0.105	0.056	1 cup	53
Orange	0.058	0.122	0.075	Medium	62
Grape	0.035	0.050	0.052	1 cup	104
Strawberry	0.070	0.218	0.106	1 cup	49
Pineapple	0.033	0.067	0.055	1 cup	83
Peach	0.039	0.099	0.058	Medium	59
Avocado	0.111	0.069	0.083	1/2 cup	120
<b>AVERAGE</b>	<b>0.050</b>	<b>0.098</b>	<b>0.064</b>		<b>75</b>

Fruits have a smaller average TOC-NQI of 0.10 per 100 calories. Typical servings contribute 0.05 to 0.10 TOC-NQI units in 50 to 100 calories, with strawberries as a clear nutrient-density standout at 0.22. Only about one in three Americans meets the minimal goal of two servings a day. Fewer still eat the USDA-recommended three to four servings for most Americans. Like vegetables, fruits are associated with reduced risk of cardiovascular diseases, obesity, some cancers, and hypertension (USDA’s *Dietary Guidelines for Americans*). Also, increased fruit consumption is the natural and far superior substitute for Americans’ excessive intake of refined sugars.

In fruits, the largest contributors to TOC-NQI are ORAC, fiber, and vitamin C. The carotenoids lutein, zeaxanthin, and lycopene contribute for a few fruits, especially lycopene in watermelon.



Four fruits deliver 0.1 or more TOC-NQI units per 100 calories

WHOLE GRAINS	NUTRITIONAL QUALITY INDEX				
	PER 100 GRAMS	PER 100 CALORIES	PER SERVING	SERVING SIZE	SERVING CALORIES
Whole wheat flour	0.191	0.056	0.054	1 ounce	97
Brown rice, raw	0.119	0.032	0.034	1 ounce	105
Corn meal, whole	0.170	0.047	0.048	1 ounce	103
Oatmeal, dry	0.171	0.045	0.049	1 ounce	108
Rye flour, dark (whole)	0.285	0.088	0.081	1 ounce	92
Wild rice, raw	0.171	0.048	0.048	1 ounce	101
Barley (whole), raw	0.221	0.062	0.063	1 ounce	101
Triticale flour, whole	0.196	0.058	0.056	1 ounce	96
Amaranth grain, raw	0.181	0.049	0.051	1 ounce	105
Kamut grain, raw	0.190	0.056	0.054	1 ounce	96
<b>AVERAGE</b>	<b>0.189</b>	<b>0.054</b>	<b>0.054</b>		<b>100</b>

Whole grains include the nutrient- and fiber-rich bran and germ of the seed kernel, both of which are removed from white flour and white rice. The germ is removed from most corn meal. Whole grains contribute about 0.05 TOC-NQI units per 100 calories, less than vegetables and fruits, but valuable as low-cost sources of protein, fiber and many other nutrients. Consumption of whole grains is increasing, but is still far short of the recommendation that at least half of total grain intake should be whole grains. Whole grains are believed to reduce risks for heart disease, stroke, obesity, cancer, type-2 diabetes, and kidney stones. The fiber in grains also helps prevent constipation.

The largest contributors to grain TOC-NQIs are fiber, protein, and ORAC. Lutein + zeaxanthin stands out in corn meal. We estimated ORAC values for most grains and grain products, based on a few available values and sometimes based on the correlation of ORAC with another measure of antioxidant capacity called TEAC. The Center is carrying out research now to deepen the nutrient-content database for grains, as part of an ongoing study on grains and grain-based products.

WHOLE GRAIN PRODUCTS	NUTRITIONAL QUALITY INDEX				
	PER 100 GRAMS	PER 100 CALORIES	PER SERVING	SERVING SIZE	SERVING CALORIES
Bread, whole wheat	0.138	0.056	0.037	1 slice	67
Bread, 7-grain (whole)	0.141	0.053	0.037	1 slice	69
Shredded Wheat cereal	0.170	0.050	0.048	1 ounce	96
Rice cake, brown rice	0.110	0.028	0.030	2 cakes	104
Wheaties cereal	0.488	0.141	0.139	1 ounce	99
Cheerios cereal	0.448	0.122	0.127	1 ounce	104
All-Bran cereal	0.767	0.295	0.218	1 ounce	74
<b>AVERAGE</b>	<b>0.323</b>	<b>0.107</b>	<b>0.091</b>		<b>87</b>

Some breads and cereals such as Shredded Wheat are made with whole wheat, so their TOC-NQIs per 100 calories are similar to whole wheat. Unlike for Shredded Wheat, the relatively higher values for Wheaties, Cheerios and All-Bran cereals reflect the presence of added nutrients, delivering 10% to 100% of the RDAs in a single serving. Nutrient fortification in these brands doubles or triples their TOC-NQIs compared to the grain ingredients alone.

The major contributors to these TOC-NQIs are fiber, protein and the added vitamins and minerals. All-Bran cereal's extraordinary nutrient density comes partly from the high fiber content of bran. However, because bran lacks the germ and starchy part of wheat kernels, it is not fully whole grain, and the cereal contains significant added sugar.

REFINED GRAIN BREADS	NUTRITIONAL QUALITY INDEX				
	PER 100 GRAMS	PER 100 CALORIES	PER SERVING	SERVING SIZE	SERVING CALORIES
Bread, wheat, enriched	0.110	0.041	0.027	1 slice	67
Bread, white, enriched	0.094	0.035	0.023	1 slice	67
Bread, rye	0.111	0.043	0.022	1 slice	52
Bread, oatmeal	0.099	0.037	0.027	1 slice	73
Bread, French	0.096	0.033	0.024	1 slice	72
Cornbread	0.075	0.024	0.021	1 ounce	89
<b>AVERAGE</b>	<b>0.098</b>	<b>0.036</b>	<b>0.024</b>		<b>70</b>

Note that the TOC-NQI per 100 grams for refined grain breads is only about 0.10 even after being "enriched," compared to about 0.15 for whole grain breads. White flour is the leading ingredient in most breads, including some with names that may suggest otherwise, such as Bran and Wheat Bread, Wheat Bread, most Multigrain Breads, and Oatmeal Bread. Only 100% Whole Wheat Bread is certain to list no white flour as an ingredient. White flour can be confusingly labeled as "flour," "wheat flour," or "unbleached flour."

The white flours used in all these breads are "enriched," meaning they contain added amounts of five nutrients that modestly boost their TOC-NQIs (thiamin, riboflavin, niacin, iron, and folate). Still, their TOC-NQIs are less than the values for whole grain breads, reflecting their losses of fiber, magnesium, potassium, vitamin B<sub>6</sub>, and other nutrients that are not added.

For good reason, concern is growing over how the planet will meet the food needs of a projected peak population of around 9 billion at some point in the future. In this light, it is worth highlighting that the approximate one-third drop in nutritional value between whole grain breads and more refined breads represents valuable and essential nutrients that were grown on the farm, harvested, and moved through the food system, but removed for the most part from the human food supply. Globally, these lost nutrients are the food supply's low-hanging fruit, if and when greater importance is placed on advancing food security for all.

USDA's *Dietary Guidelines* recommend reduced consumption of refined grains. The leading contributors to the depleted TOC-NQIs shown here are protein, fiber and ORAC, including for white bread.

REFINED GRAIN CEREALS	NUTRITIONAL QUALITY INDEX				
	PER 100 GRAMS	PER 100 CALORIES	PER SERVING	SERVING SIZE	SERVING CALORIES
Corn Flakes cereal	0.323	0.089	0.092	1 ounce	103
Corn Pops cereal	0.254	0.065	0.072	1 ounce	110
Rice Krispies cereal	0.333	0.086	0.095	1 ounce	110
Special K cereal	0.557	0.147	0.158	1 ounce	108
Froot Loops cereal	0.288	0.077	0.082	1 ounce	106
Frosted Cheerios cereal	0.329	0.087	0.094	1 ounce	107
<b>AVERAGE</b>	<b>0.348</b>	<b>0.092</b>	<b>0.099</b>		<b>107</b>

Refined grain cereals generally lack bran and germ, and most of them contain 20% to 40% added sugar. However, because of substantial additions of some nutrients, their average TOC-NQI of about 0.09 per 100 calories looks much better than refined grain breads (0.02 to 0.04 per 100 calories) and better even than whole grains (about 0.05 per 100 calories). The added nutrients dominate these TOC-NQIs. Unfortunately, the added nutrients do not make up for refining losses such as fiber, magnesium, potassium, and ORAC. Despite the added nutrients that enhance TOC-NQIs, the USDA recommends reducing consumption of refined grain products and choosing whole grain cereals with minimal added sugar.

DAIRY FOODS	NUTRITIONAL QUALITY INDEX				
	PER 100 GRAMS	PER 100 CALORIES	PER SERVING	SERVING SIZE	SERVING CALORIES
Milk, whole (3.3% fat)	0.030	0.049	0.073	1 cup	149
Milk, 2% fat	0.028	0.056	0.068	1 cup	122
Milk, 1% fat	0.028	0.067	0.068	1 cup	102
Milk, nonfat	0.028	0.083	0.069	1 cup	83
Milk, soy (fortified)	0.036	0.084	0.088	1 cup	104
Cheese, cottage, 4.5% fat	0.038	0.039	0.044	1/2 cup	111
Cheese, cottage, 1% fat	0.038	0.053	0.043	1/2 cup	81
Cheese, American	0.110	0.029	0.031	1 oz.	106
Cheese, Cheddar	0.120	0.030	0.034	1 oz.	114
Egg, raw	0.111	0.078	0.056	1 large	72
<b>AVERAGE</b>	<b>0.057</b>	<b>0.057</b>	<b>0.057</b>		<b>105</b>

Milk is an important source of high-quality protein, calcium and added vitamin D in most American diets. As the fat and its calories are progressively removed from whole milk to make reduced-fat milk

and dairy products, the TOC-NQI per 100 calories increases, because few nutrients are removed with the fat, and the calories decline substantially. However, the TOC-NQI per serving declines slightly, because of the loss of linolenic acid, an omega-3 fat. (Other omega-3 fats, conjugated linoleic acids, and other beneficial substances not included in the TOC-NQI, are also removed, so some may choose whole milk despite its lower TOC-NQI.) The broad nutrient density of eggs is well above most other dairy products. Note: Reliable ORAC data are not presently available for dairy products. When they become available, they will likely increase the NQIs shown here, perhaps substantially.

Soy milk has higher amounts of some nutrients than cow's milk, and is often fortified with calcium and vitamins A, B12, and D, to levels similar to cow's milk. During cheese making, fat and calories are concentrated, but some nutrients in milk are lost in the removed whey. These changes and the lack of added vitamin D decrease the TOC-NQIs per 100 calories for cheeses, especially for solid cheeses such as American and Cheddar.

On average, American adults consume about half of the USDA-recommended 3 cups per day of reduced-fat milk and milk products. These products (but not fatty cheeses) are recommended for bone health and reduced risk of heart disease, type-2 diabetes, and hypertension (USDA's *Dietary Guidelines for Americans*). Protein, vitamin D, and calcium are the leading contributors to most of these TOC-NQIs. In eggs, choline and lutein + zeaxanthin stand out.

MEATS AND SEA FOODS	NUTRITIONAL QUALITY INDEX				
	PER 100 GRAMS	PER 100 CALORIES	PER SERVING	SERVING SIZE	SERVING CALORIES
Ground beef, cooked (15% fat)	0.109	0.047	0.092	3 OZ.	198
Calf liver, braised	0.659	0.343	0.562	3 OZ.	164
Pork loin, roasted	0.119	0.048	0.101	3 OZ.	211
Pork spareribs, roasted	0.113	0.047	0.096	3 OZ.	203
Chicken, whole, roasted	0.103	0.043	0.087	3 OZ.	204
Chicken breast, fast food	0.093	0.031	0.079	3 OZ.	258
Salmon, Atlantic, baked	0.196	0.095	0.167	3 OZ.	176
Tuna, light, canned in water	0.127	0.109	0.108	3 OZ.	99
Catfish, baked	0.080	0.056	0.068	3 OZ.	123
Shrimp, boiled	0.104	0.088	0.089	3 OZ.	101
<b>AVERAGE</b>	0.170	0.091	0.145		174

Meats and sea foods supply high quality protein and many other nutrients. Besides protein, leading contributions to TOC-NQI come from vitamin B12 in beef, calf liver, and sea foods, thiamin in pork, linoleic acid and niacin in chicken, vitamin D in salmon and tuna, and choline in catfish and shrimp. All these foods are important sources of many other nutrients, including linolenic acid and other omega-3 fatty acids in sea foods and chicken. Calf liver is an extraordinarily rich and diverse food.

According to the USDA, some Americans need to increase their intake of protein foods, while most get more than recommended levels, especially of beef (USDA's *Dietary Guidelines for Americans*).

Based on evidence that the omega-3 fatty acids EPA and DHA help prevent heart disease and death from heart disease, USDA recommends that Americans increase their consumption of a variety of sea foods to 8 ounces per week, especially those low in mercury. For similar reasons about heart health, USDA also recommends that some animal protein sources be replaced with peanuts and nuts (not shown).

SWEETS AND ADDED FATS	NUTRITIONAL QUALITY INDEX				
	PER 100 GRAMS	PER 100 CALORIES	PER SERVING	SERVING SIZE	SERVING CALORIES
Sugar	0.001	0.000	0.000	1 Tbsp.	49
Honey	0.005	0.002	0.001	1 Tbsp.	64
Oil, soybean	0.431	0.049	0.059	1 Tbsp.	120
Oil, olive	0.110	0.012	0.015	1 Tbsp.	119
Butter	0.061	0.009	0.003	1 pat	36
Margarine (stick)	0.137	0.022	0.007	1 pat	31
Coke and Pepsi Colas	0.001	0.002	0.002	12 fl. oz.	136
Gatorade, fruit-flavored	0.001	0.005	0.007	20 fl. oz.	158
Cookie, Oreo	0.112	0.024	0.038	3 each	159
Cookie, animal crackers	0.069	0.015	0.020	1 oz.	127
Caramel candies	0.038	0.010	0.011	1 oz.	108
Chocolate chips, semisweet	0.214	0.045	0.061	1 oz.	136
<b>AVERAGE</b>	0.098	0.016	0.019		104

Refined sugars, added fats, and foods high in these ingredients rank mostly at the bottom of the nutrient density scale, with TOC-NQIs of 0.00 to 0.02 per 100 calories. In its *Dietary Guidelines for Americans*, USDA recommends minimizing most of these foods with low nutrient density. However, it distinguishes between sugars and solid fats on one hand (including butter and margarine), and oils on the other hand, because oils contain some valuable nutrients. The relatively high TOC-NQI for soy oil, for example (0.049 per 100 calories), comes mainly from linoleic and linolenic acids, with only 0.008 per 100 calories from other nutrients.

Olive oil contains relatively little of these nutrients, as it contains mostly monounsaturated fats (not included in TOC-NQI). Most of the TOC-NQI for chocolate chips and some of the TOC-NQI for Oreo cookies comes from ORAC, with contributions also from other nutrients in cocoa beans. USDA notes that soft drinks and sports drinks like Gatorade are leading sources of refined sugars in American diets, and many Americans drink too much of them. The partial hydrogenation used to make stick margarines destroys some linoleic and linolenic acids and has the further disadvantage of producing unhealthy *trans* fatty acids.

### III. APPLYING THE TOC-NQI TO COMBINATIONS OF FOODS AND DAILY DIETS

TOC-NQIs can be calculated for food mixtures such as sandwiches, other entrees, recipes, complete meals and even complex diets. Potentially two different methods can be used.

#### METHOD 1

For many relatively common and simple food mixtures, the USDA reports the nutrient contents of the mixtures in the same way that it does for single foods, and the TOC-NQI calculation proceeds in the same way as well. Some examples are shown below.



FAST FOODS & OTHER MIXTURES	NUTRITIONAL QUALITY INDEX				
	PER 100 GRAMS	PER 100 CALORIES	PER SERVING	SERVING SIZE	SERVING CALORIES
Big Mac with cheese	0.130	0.023	0.271	1 each	1177
French fries, McDonalds	0.148	0.027	0.168	Medium	616
Shrimp, breaded, fast food	0.094	0.021	0.154	6-8 shrimp	745
Onion rings, breaded, fast food	0.031	0.011	0.025	8-9 rings	229
Pizza Hut cheese pizza	0.100	0.039	0.096	1 slice	250
Chicken pot pie	0.109	0.024	0.237	1 pie	1007
Ice cream, vanilla	0.026	0.019	0.017	1/2 cup	90
Ham & cheese sandwich	0.094	0.027	0.138	1 each	514
Burrito, bean & cheese	0.107	0.028	0.198	2 each	703
Fried chicken, fast food	0.152	0.031	0.248	Breast & wing	805
<b>AVERAGE</b>	0.099	0.025	0.155		614

Notice in these examples that the TOC-NQIs per 100 calories are low compared to most whole foods, because of the substantial additions of frying fat, refined sugar, and white flour. For example the TOC-NQIs per 100 calories are 0.023 for a Big Mac, compared to 0.047 for ground beef, 0.027 for French fries compared to 0.051 for boiled potato, 0.021 for fried and breaded shrimp compared to 0.088 for boiled shrimp, and 0.011 for fried and breaded onion rings compared to 0.061 for boiled onions.

#### METHOD 2

For food mixtures, entrees, meals and diets that are not reported by USDA, the calculation of TOC-NQI is more complex. It requires adding up the weights, calories, and 27 nutrients from each of the individual foods in the mixtures. The summed values are then used in the same way as for single foods. Some commercially available recipe and diet analysis programs can perform the needed

summations. We use NutriCircles software (Strickland Computer Consulting, 2011), which contains nearly 4,000 foods and mixtures from the USDA's current Nutrient Database for Standard Reference.

Alternatively, the nutrient content of food mixtures can be measured by a qualified laboratory, a process that would cost over \$2,000 per sample. One analytical laboratory charges \$600 to \$800 for just the mandatory nutrients on a Nutrition Facts food label, which does not include 20 nutrients needed to calculate TOC-NQIs.

# Nutrition Facts

Serving Size 1/2 cup dry (40 g)  
 Servings Per container: 13

Amount Per Serving

**Calories** 150      **Calories from Fat** 25

**% Daily Value\***

<b>Total Fat</b> 3 g	<b>4%</b>
Saturated Fat 0.5 g	<b>2%</b>
Trans Fat 0 g	<b>0%</b>
<b>Cholesterol</b> 0 mg	<b>0%</b>
<b>Sodium</b> 0 mg	<b>0%</b>
<b>Total Carbohydrate</b> 27 g	<b>9%</b>
Dietary Fiber 4 g	<b>15%</b>
Sugars 1 g	
<b>Protein</b> 5 g	
<b>Vitamin A</b>	<b>0%</b>
<b>Vitamin C</b>	<b>0%</b>
<b>Calcium</b>	<b>0%</b>
<b>Iron</b>	<b>10%</b>

\*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.

		<b>Calories:</b>	2,000	2,500
Total Fat	Less than		65 g	80 g
Sat Fat	Less than		20 g	25 g
Cholesterol	Less than		300 mg	300 mg
Sodium	Less than		2,400 mg	2,400 mg
Total Carbohydrate			300 g	375 g
Dietary Fiber			25 g	30 g

#### IV. COMPARISON TO OTHER TOOLS FOR MEASURING FOOD NUTRITIONAL QUALITY

We are what we eat, and what we eat plays a direct role in how we feel and whether we sustain good health throughout life. In addition, science is shining an ever-brighter light on the consequences of dietary choices, arming people with valuable information on the importance of food and dietary choices.

Deepened interest and concern over the nutritional quality of food has led to the development of a number of quantitative “nutrient profiling” systems that rank foods in accord with some defined set of nutritional attributes, which can include both positive and negative qualities (see Drewnowski and Fulgoni, 2007 for an excellent overview). One of the first such systems was introduced in a paper published in 1973 (Hansen, 1973). The system was later dubbed the “Nutritional Quality Index” in a book published in 1979 (Hansen et al., 1979). Hansen’s NQI was based on the amounts of 18 nutrients in 2,000 calories of food, relative to the RDAs for those nutrients. It was a nutrient-by-nutrient profiling system and did not aggregate scores across nutrients to create a composite score for a given food.

Some nutrient profiling schemes restrict their coverage to just those nutrients listed in the nutritional labeling on food products. Others strive to develop a relationship, or ratio, between beneficial nutrients in food relative to undesirable components like saturated fat and sodium. None of these systems aspire to estimate the total or relative nutritional quality of a given food or meal based on all or most known, essential nutrients.

Many of these systems were developed to provide advice on food choices for people hoping to prevent or slow the progression of a defined health problem, like obesity or cardiovascular disease. These limited systems are not addressed here. See Drewnowski (2005) for a solid review.

The Organic Center’s “Nutritional Quality Index” (TOC-NQI) was designed to overcome limitations in past nutrient profiling systems. It produces nutritional quality rankings based on an extensive appraisal of the known nutrients in foods. In this section, we compare and contrast the TOC’s NQI to several other nutrient profiling systems, highlighting strengths, weaknesses, and appropriate applications.

##### COMMON SYSTEM DESIGN COMPONENTS

Contemporary nutrient profiling systems like the TOC-NQI share several basic design features and tend to draw on the same sources of data. All systems take multiple nutrients into account. Most systems currently in use encompass two to 23 nutrients (Drewnowski and Fulgoni, 2007), while the TOC-NQI includes 27 nutrients. Accordingly, our system is one of the most comprehensive designed to date.

All nutritional quality indices calculate nutrient amounts for a defined quantity of food, relative to a set of recommended average daily intakes. The quantity of food may be a serving, 100/1,000/2,000 calories worth, or 100 grams. The recommended intakes may be the U.S. Food and Nutrition Board’s Recommended Dietary Allowances (RDAs) and Adequate Intakes (AIs), as used by the TOC-NQI.

They may be the U.S. Food and Drug Administration's "Daily Values" (DVs) used for food labeling, or some other "Recommended Daily Intakes" (RDIs) in the nutrient profiling literature. All indices use the nutrient amounts in specific foods, as reported in USDA's Nutrient Database for Standard Reference.

Nutrient profiling systems typically then add up the shares of RDAs/AIs/DVs/RDIs across the nutrients encompassed in the system, and the sum is the score per serving, or 100/1,000/2,000 calories, or 100 grams.

While most systems are conceptually similar, there are many variations on the theme. The distinguishing characteristics across the systems include –

- ◆ Is the system focused on individual foods or diets, or both?
- ◆ Are the food quality indices calculated per serving, and/or per 100/1,000/2,000 calories, and/or per 100 grams?
- ◆ Which nutrients are included?
- ◆ How are "recommended" intakes established for those nutrients lacking a well accepted, government endorsed RDA/AI/DV/RDI?
- ◆ How are nutrient data gaps dealt with, since the USDA's Nutrient Database for Standard Reference does not cover all relevant nutrients for all foods?
- ◆ Are all nutrients assigned equal weights in the index, and if not, how and on what basis are weights adjusted up or down for specific nutrients?
- ◆ Does the system deal in some fashion with foods that contain extraordinarily high levels of specific nutrients, especially when calculating nutritional quality per 100, 1,000, or 2,000 calories? If specific nutrient values are truncated to avoid skewing aggregate scores across all nutrients, how is this done?
- ◆ Are index scores adjusted downward for negative attributes such as *trans* fat, saturated fat, salt, and/or sugar content, and if so, how?
- ◆ Does the system account for differences in the nutrient content of food based on growing system (e.g., conventional versus organic)?
- ◆ Does the system account for differences in food form (e.g., dried, frozen, fresh, or boiled)?
- ◆ Can the system estimate the nutritional quality of complex food mixtures and diets, or just single-ingredient foods?
- ◆ Are the equations and technical specifications open-source and transparent or proprietary?

The Organic Center developed its own system because none of the "open-source" systems –

- ◆ Includes the list of nutrients often considered most vital in promoting good health;
- ◆ Adjusts the weights assigned to the nutrients in light of the adequacy/inadequacy of typical daily intakes;
- ◆ When information is available to support such changes, adjusts nutrient content values for the impact of farm production systems on nutrient density (e.g., organic versus conventional farming); and
- ◆ Explicitly provides for separate quality indices for diverse populations, such as males and females of widely varying age, or those with special nutritional needs due to environment or health status.

The following sections describe three of the most widely used contemporary nutrient profiling systems. They include comparisons with the TOC-NQI for common foods.

#### A. "NUTRIENT-RICH FOODS" INDEX (NRF)

Dr. Adam Drewnowski, an economist at the University of Washington in Seattle, has worked on nutrient profiling systems for many years



and has developed the "Nutrient-Rich Foods" index (Fulgoni, Keast, and Drewnowski, 2009). The most recent version of this index encompasses 12 nutrients, 9 to encourage—protein, fiber, vitamins A, C, and E, calcium, magnesium, iron, and potassium—and 3 nutrients to limit—saturated fat, sodium, and added sugars.

Originally Drewnowski included several additional nutrients, based on those emphasized by organizations such as the Women, Infants, and Children (WIC) program, the National Cancer Institute, and FAO. He and his coworkers then tested several versions of the index for their ability to rate how well thousands of representative American diets matched the Healthy Eating Index (HEI), a measure of diet quality based on the 2005 *Dietary Guidelines for Americans*. (The HEI is described more fully below.) The most successful index included 9 nutrients to encourage and 3 to limit, and is dubbed the NRF 9.3 index. (We will call it the NRF index.)

All 12 nutrients are equally weighted in the NRF index, implying that all of them are equally important and that needs and intakes do not differ by sex or age. Drewnowski (2005) notes that a weighting system in the NRF indices "...could be based on the distribution and the relative rarity of the nutrients in the food supply." The TOC-NQI encompasses this refinement and varies the weights assigned to individual nutrients for different population groups to reflect the groups' average degree of adequacy/inadequacy in current intakes.

NRF indices are calculated for two different amounts of food—for 100 calories and for FDA serving sizes called Reference Amounts Customarily Consumed (RACC). In both cases, the 12 nutrient amounts in each food are first expressed as percentages of the FDA's corresponding Daily Value (DV) used for food labeling purposes. The NRF index is simply an equally weighted sum of the 9 percentages for nutrients to be encouraged, minus the sum of 3 percentages for nutrients to be limited.

The percentages used in the above calculation are capped at 100% for the 9 nutrients to be encouraged. This truncation mainly reduces NRF contributions for vitamins A and C in a small number of vegetables. Although it might seem much stronger than the TOC-NQI's truncation at 500% of the RDA or AI, our truncation was limited almost entirely to two nutrients not included in the NRF index, vitamin K and lutein + zeaxanthin.

The FDA's DVs for nutrients are based on historical RDAs and sometimes differ from the current RDAs used in our TOC-NQI. For example, the DV for vitamin C is 60 mg, compared to the current adult RDA of 75 mg for women and 90 mg for men. The DVs for vitamins E and B12 are at least twice the current

adult RDAs. The NRF indices presumably use DVs instead of RDAs, because there are DVs, but no RDAs, for the saturated fat and added sugar that make negative contributions to the NRF indices.

Table 4.1 compares a few NRF scores to TOC-NQI scores that have been adjusted so that they both have the same value for the highest food, raw spinach. Both scores are on a per-calorie basis.

FOOD	NRF PER 100 CALORIES	TOC-NQI PER 100 CALORIES, ADJUSTED	NRF/ADJUSTED TOC-NQI
SPINACH, raw	695	695	1.0
BROCCOLI, cooked	422	360	1.2
STRAWBERRIES	376	178	2.1
TOMATO	249	204	1.2
ORANGE	242	99	2.4
WATERMELLON	87	97	0.9
MILK, nonfat	84	68	1.2
CHEERIOS	79	99	0.8
BANANA	52	38	1.4
APPLE	47	68	0.7
CHICKEN BREAST, cooked	39	53	0.7
SALMON, Atlantic, cooked	36	77	0.5
PORK LOIN, cooked	34	39	0.9
MILK, whole	26	40	0.7
EGG	20	64	0.3
BREAD, 100% whole wheat	20	46	0.4
BREAD, white	11	29	0.4
OLIVE OIL	1	10	0.1
BUTTER	-9	7	
COLA	-56	1	

**Table 4.1.** Nutrient-Rich Food (NRF) indices compared to adjusted TOC-NQI indices, both on a per-calorie basis.

There is an obvious correlation between these two measures of nutrient density, with high and low values of both indices clustered at the top and bottom, respectively. Although NRF scores can be substantially negative, and TOC-NQI values never are, the last five foods in this list have the same rank in both indices. The ratio of the two indices in the last column shows the variability between the indices. Compared to TOC-NQI values, the NRF values are relatively high for strawberry and orange, and relatively low for breads, egg and olive oil. Both indices clearly show the expected higher nutrient density of whole wheat bread over white bread and of nonfat milk over whole milk (see above

discussion of TOC-NQIs for dairy foods).

For NRF scores based on serving sizes (RACC), the correlation with TOC-NQI values per serving is considerably smaller than shown above for per-calorie values. Presumably this difference reflects differences between the serving sizes used in the two indices.

#### B. "OVERALL NUTRITIONAL QUALITY INDEX" (ONQI, ALSO KNOWN AS NuVal)

A team led by Dr. David Katz at the Yale University School of Medicine and Griffin Hospital developed the ONQI. This system is supported by a distinguished panel of consulting experts. The Preface to the ONQI "Reference Manual" states that –



"Healthful eating and activity patterns (along with sensible behaviors, such as tobacco avoidance) could reduce the rate of heart disease by as much as 80%, diabetes by up to 90%, and cancer by nearly 60%."

The ONQI is designed to improve dietary patterns "one food choice at a time." It ranks foods based on relative nutrient content, both across all foods and within food groups. It is applicable to single foods, food mixtures, meals, daily intakes, and overall dietary patterns.

The ONQI algorithm is proprietary, but involves ratios of nutrient intakes relative to undisclosed recommended intakes. It encompasses both macro- and micro-nutrients. ONQI produces scores and rankings through an iterative process that modifies objective ONQI scores with subjective considerations by the expert consulting panel. It is not clear how often and in what ways this process alters the final ONQI scores.

NuVal, LLC was established in 2008 to license use of ONQI to food companies and retailers. At present, 17 supermarkets (mostly regional chains) are using the system. NuVal scores are given for brand name products, and thus presumably take into account differences in product ingredients and cooking methods. The NuVal website provides limited explanation of the ONQI algorithm with a representative sample of NuVal scores for dozens of foods, organized by food group. Some examples are shown in Table 4.2 below, compared to TOC-NQIs per 100 calories, adjusted so that both indices have the same value for the highest food, broccoli.

FOOD	NuVal ONQI	TOC-NQI PER 100 CALORIES, ADJUSTED	NuVal ONQI/ ADJUSTED TOC-NQI
BROCCOLI, cooked	100	100	1.0
BLUEBERRIES	100	27	3.8
GRAPEFRUIT, pink	99	24	4.0
PINEAPPLE	99	15	6.5
TOMATO	96	57	1.7
MILK, nonfat	91	19	4.8
BANANA	91	11	8.5
AVOCADO	89	16	5.7
SALMON, Atlantic, cooked	87	22	4.0
LETTUCE, iceberg	82	59	1.4
MILK, 1% fat	81	15	5.3
SHRIMP	75	20	3.8
CHERRIOS	37	28	1.3
BREAD, 100% whole wheat	37	13	2.9
PORK LOIN, cooked	35	11	3.2
GROUND BEEF	30	11	2.8
HAM	27	14	1.9
BREAD, white	27	8	3.4

**Table 4.2.** NuVal Overall Nutritional Quality Indices (ONQIs) indices compared to adjusted TOC-NQIs per 100 calories.

NuVal ONQI values are mostly in the range of 80 to 100 for fruits, vegetables, milk and fish. ONQIs are much smaller for grains and meats, ranging mostly from 20 to 40. A few fish, vegetables, and other foods have intermediate values (not shown). There is little apparent correlation with TOC-NQIs per 100 calories, so the ONQIs do not strongly reflect nutrient density. Similarly, there is little or no correlation with TOC-NQIs per serving (not shown).

### C. "AGGREGATE NUTRIENT DENSITY INDEX" (ANDI)

The for-profit organization "Eat Right America" developed the ANDI index to identify those foods that deliver the most nutrition per calorie consumed. The company offers a range of nutrition consulting services to companies that can become partners or subscribers at various levels.



ANDI scores are based on nutrient amounts per 1,000 calories, and hence are comparable to the TOC-NQIs per 100 calories. ANDI scores encompass the 21 minerals, vitamins, and measures of antioxidant

activity shown here –

- ◆ Calcium
- ◆ Carotenoids: beta-carotene, alpha-carotene, lutein + zeaxanthin, and lycopene (apparently a proprietary composite)
- ◆ Fiber
- ◆ Folate
- ◆ Glucosinolates
- ◆ Iron
- ◆ Magnesium
- ◆ Niacin
- ◆ Selenium
- ◆ Zinc
- ◆ Vitamin B<sub>1</sub> (thiamin)
- ◆ Vitamin B<sub>2</sub> (riboflavin)
- ◆ Vitamin B<sub>6</sub>
- ◆ Vitamin B<sub>12</sub>
- ◆ Vitamin C
- ◆ Vitamin E
- ◆ ORAC

For each of these 21 nutrient factors, the amounts in 1,000 calories of a given food are first expressed as a ratio to its RDA or other estimate of daily need. The ANDI score is an equally weighted sum of these ratios, except that ORAC is doubly weighted. For nutrient factors without RDAs, estimated needs "...were established based on available research and current understanding of the benefits of these factors."

The major differences between ANDI and TOC-NQI scores, in terms of the nutrients included and nutrient weights, are –

- ◆ ANDI scores do not include protein, linoleic acid, linolenic acid, choline, copper, phosphorus, potassium, or vitamins D and K. They also do not include animal sources of vitamin A (retinol) or vegetable sources except for the contribution of beta-carotene to the carotenoid composite. Lycopene and lutein + zeaxanthin are included in the same composite, instead of separately in the TOC-NQI.
- ◆ ANDI scores for grain and dairy products, nuts, and beans likely do not include any contribution from their doubly-weighted ORAC component, as ORAC data is not generally available for these foods. TOC-NQI scores for grain products include estimated ORAC values.
- ◆ TOC-NQI values do not include alpha-carotene or glucosinolates. (The latter are sulfur-containing substances found in broccoli, Brussels sprouts, and other cabbage family members. During human digestion they are converted to thiocyanates and isothiocyanates, and are believed to help prevent bowel and other cancers.)
- ◆ The nutrients in ANDI scores are not weighted according to their adequacy or deficiency in average diets.

ANDI scores also do not adjust for changes in nutrient content brought about by farming systems, and hence do not distinguish between conventional and organic foods. The "Eat Right America" website

notes that the company will need “reliable data on a broad array of organic foods grown in various regions and soils” before making such adjustments.

All ANDI scores are adjusted to a 1,000-point scale, with the most nutrient dense food – kale – set at 1,000. Table 4.3 provides a comparison of ANDI and TOC-NQI scores for selected foods, based on the same 1,000-point scale. There are no ANDI scores per serving or per food weight, and no scores for food mixtures, recipes, or diets.

FOOD	ANDI PER 1000 CALORIES	TOC-NQI PER 100 CALORIES, ADJUSTED	ANDI/ADJUSTED TOC-NQI
KALE, boiled	1000	1000	1.0
CABBAGE, raw	481	313	1.5
LETTUCE, Romaine	389	1008	0.4
BROCCOLI, boiled	376	581	0.6
CARROT, boiled	240	338	0.7
STRAWBERRY	212	286	0.7
TOMATO	164	329	0.5
ORANGE	109	161	0.7
APPLE	72	109	0.7
SALMON, Atlantic, cooked	39	125	0.3
AVOCADO	37	91	0.4
MILK, nonfat	36	109	0.3
POTATO, boiled, peeled	31	67	0.5
BANANA	30	62	0.5
EGG, raw	27	103	0.3
CHICKEN BREAST, cooked	27	86	0.3
BREAD, whole wheat	25	73	0.3
BREAD, white	18	46	0.4
OLIVE OIL	9	16	0.5
COLA	1	2	0.5

**Table 4.3.** Comparison of ANDI and TOC-NQI Values for Representative Foods. Both indices are on a per-calorie basis, with TOC-NQI values scaled to match the defined value of 1000 for Kale in the ANDI system.

There is an obvious correlation between ANDI and TOC-NQI scores, with large and small values of both indices clustering respectively near the top and bottom of the list. The last column also shows variation in the ratio of the two indices, and a trend for the ratio to be highest for green vegetables and fruits. In other words, ANDI values are disproportionately large for green vegetables and fruits compared to the TOC-NQI. The reasons are unclear, as details of the ANDI algorithm are not available.

The explanation may relate to details of the carotenoid composite and possible truncation of carotenoids and other nutrients.

#### D. MILESTONES IN THE GOVERNMENT'S QUEST TO DEFINE "HEALTHY" FOODS

The U.S. Federal Trade Commission suggested one of the first systems to rate nutritional quality in 1974, proposing that the term "nutritious" could be used in the marketing of only those foods that delivered –

- ◆ 10% of the protein RDA and 10% of at least three other nutrients per 100 calories, and
- ◆ At least 10% of the RDA per serving for one of these three nutrients.

This proposal was quickly dropped when it became evident that only one vegetable and one milk product out of 135 tested met the standard. Similar, but less restrictive, proposals followed, none of which has been widely adopted.

In the 1980s, focus shifted to specifying the criteria applicable to foods labeled as a "good source of..." (10-19% of the DV or RDA in a reference amount, like a serving) or an "excellent source of..." (20% or more of the DV or RDA). Similar criteria were adopted for "reduced..." or "low..." labeling for nutrients considered to be excessively consumed in typical American diets: fat, saturated fat, cholesterol, and sodium.

The FDA formally set forth a definition of "healthy" foods in the 1990s, and provided further details in its 2002 revision of the Subpart in the Code of Federal Regulations setting forth the rules governing health claims on food product labels. A "healthy" food is one that –

- ◆ Contains at least 10% of the RDA or "daily reference value" of one of six key nutrients (protein, fiber, vitamins A and C, calcium, or iron),
- ◆ Is low in fat (less than 3 grams per reference amount, usually one serving),
- ◆ Is low in saturated fat (less than 1 gram),
- ◆ Is low in cholesterol (less than 60 mg), and
- ◆ Is low in sodium (less than 480 mg)

The USDA has its own system and set of criteria, and defines foods of "minimum nutritional value" as those providing less than 5% of the RDA or DV per serving for eight key nutrients (protein, calcium, iron, vitamins A and C, riboflavin, thiamin, and niacin).

#### "HEALTHY EATING INDEX" (HEI)

In 1995 the USDA conceived a measure of diet quality based on contemporary, federal guidelines, the Healthy Eating Index. Although it is not a nutrient profiling system, it has been applied by USDA to a number of special nutrition research projects that strive to determine how closely dietary patterns conform to the government-recommended *Dietary Guidelines for Americans*.

The HEI contains 10 components. Five assess the adequacy of intakes in the five major food groups (fruits, vegetables, milk, grains, and meats), and another four reflect components of the diet that should be consumed in moderation (total and saturated fat, cholesterol, and sodium). The tenth component measures dietary diversity.



The foods consumed by a given population, or an individual, are rated from 1 to 10 in each of the 10 components. An aggregate score of 80 or higher is regarded as “good” dietary choices, a score in the 51-80 range “needs improvement,” and a score below 51 is regarded as “poor.”

Scores within a food group category are a function of the number of servings consumed relative to the number of servings recommended.

## APPENDIX. DETAILS IN THE CALCULATION OF TOC-NQI VALUES FOR SPECIFIC FOODS

## TOC-NQI CALCULATION OF INDEX WEIGHTS

The index weights for women age 19 to 30 are shown in the final column I of the table below. Details for each step of the calculation are described below the table.

A	INDEX WEIGHTS FOR WOMEN AGE 19 TO 30							
	B	C	D	E	F	G	H	I
27 NUTRIENTS & CALORIES	RDA	UNITS	INTAKE	INTK/ RDA	SHARE	DEF- IC.	SH*DEF	INDEX WT.
Calories	2200	calories						
Vitamin A	700	mcg	607	0.87	0.024	1.15	0.028	0.024
Vitamin D	15	mcg	4.6	0.31	0.024	3.26	0.078	0.069
Vitamin E	15	mg	7.2	0.48	0.024	2.08	0.050	0.044
Vitamin K	90	mcg	88.9	0.99	0.024	1.01	0.024	0.021
Vitamin B <sub>6</sub>	1.3	mg	1.91	1.47	0.024	0.68	0.016	0.014
Vitamin B12	2.4	mcg	5.19	2.16	0.024	0.46	0.011	0.010
Vitamin C	75	mg	84.2	1.12	0.024	0.89	0.021	0.019
Folate	400	mcg	527	1.32	0.024	0.76	0.018	0.016
Niacin	14	mg	23.9	1.71	0.024	0.59	0.014	0.012
Riboflavin	1.1	mg	2.16	1.96	0.024	0.51	0.012	0.011
Thiamin	1.1	mg	1.59	1.45	0.024	0.69	0.017	0.015
Calcium	1000	mg	946	0.95	0.024	1.06	0.025	0.022
Potassium	4700	mg	2509	0.53	0.024	1.87	0.045	0.039
Magnesium	310	mg	277	0.89	0.024	1.12	0.027	0.024
Phosphorus	700	mg	1297	1.85	0.024	0.54	0.013	0.011
Copper	0.9	mg	1.3	1.44	0.024	0.69	0.017	0.015
Iron	18	mg	14.7	0.82	0.024	1.22	0.029	0.026
Selenium	55	mcg	104.9	1.91	0.024	0.52	0.013	0.011
Zinc	8	mg	11.6	1.45	0.024	0.69	0.017	0.015
Choline	425	mg	305	0.72	0.024	1.39	0.033	0.029
Fiber	25	grams	15.2	0.61	0.10	1.64	0.164	0.144
Linoleic acid	12	grams	14.5	1.21	0.05	0.83	0.041	0.036
alpha-Linolenic acid	1.1	grams	1.4	1.27	0.05	0.79	0.039	0.034
Protein	46	grams	76.2	1.66	0.16	0.60	0.097	0.085
Lutein + Zeaxanthin	2000	mcg	1362	0.68	0.05	1.47	0.073	0.064
Lycopene	10000	mcg	5219	0.52	0.03	1.92	0.057	0.050
ORAC (total)	20000	μmol TE	10000	0.50	0.08	2.00	0.160	0.140
SUMS					1.000		1.141	1.000

Column A. The 27 nutrients in the index, plus calories

Column B. RDAs, AIs, and estimated AIs used

Column C. Units used for columns B and D

Column D. Average intakes for U.S. women, age 19 to 30, NHANES 2001-2002

Column E. Average intakes as a fraction or multiple of the RDAs (column D/column B)

Column F. Initial share weights for each nutrient (column F sum = 1)

Column G. Average "deficiencies" for U.S. women (1/column E)

Column H. Index weights before normalization (column F × column G)

Column I. Normalized index weights (column H/column H sum) (column I sum = 1)

## TOC-NQI CALCULATIONS FOR RAW SPINACH

Columns L and O below show the contributions of 27 nutrients to two TOC-NQIs for raw spinach—per 100 g and per 100 calories. Details for each column are described below the table.

	J	K	L	M	N	O
	CONTENT	RDAs	NQI	CONTENT	RDAS	NQI
Weight, g	100			435		
Calories	23.0			100		
Vitamin A	470	0.671	0.016	2043	2.919	0.071
Vitamin D	0	0.000	0.000	0	0.000	0.000
Vitamin E	2.0	0.133	0.006	8.7	0.580	0.025
Vitamin K	483	1.150**	0.024	2100	5.000*	0.106
Vitamin B-6	0.195	0.150	0.002	0.848	0.652	0.009
Vitamin B-12	0	0.000	0.000	0	0.000	0.000
Vitamin C	28	0.373	0.007	122	1.623	0.030
Folate	194	0.485	0.008	843	2.109	0.034
Niacin	0.72	0.051	0.001	3.13	0.224	0.003
Riboflavin	0.189	0.172	0.002	0.822	0.747	0.008
Thiamin	0.078	0.071	0.001	0.339	0.308	0.004
Calcium	99	0.099	0.002	430	0.430	0.010
Potassium	558	0.119	0.005	2426	0.516	0.020
Magnesium	79	0.255	0.006	343	1.108	0.026
Phosphate	49	0.070	0.001	213	0.304	0.003
Copper	0.13	0.144	0.002	0.57	0.628	0.009
Iron	2.7	0.150	0.004	11.7	0.652	0.017
Selenium	1.0	0.018	0.000	4.3	0.079	0.001
Zinc	0.53	0.066	0.001	2.30	0.288	0.004
Choline	19.3	0.045	0.001	83.9	0.197	0.006
Fiber	2.2	0.088	0.013	9.6	0.383	0.055
Linoleic Acid	0.026	0.002	0.000	0.113	0.009	0.000
alpha-Linolenic Acid	0.138	0.125	0.004	0.600	0.545	0.019
Protein	2.9	0.063	0.005	12.6	0.274	0.023
Lutein+Zeaxanthin	12198	1.150*	0.074	53035	5.000**	0.321
Lycopene	0	0.000	0.000	0	0.000	0.000
ORAC_Total	1513	0.076	0.011	6578	0.329	0.046
	<b>NQI per 100 g</b>		0.196	<b>NQI per 100 calories</b>		0.852

Column J. Nutrient contents per 100 g raw spinach, from USDA no. 11457 (same units as column C)

Column K. Nutrient contents per 100 g in RDA units, column J/column B (see footnotes)

Column L. Contributions to NQI per 100 g, column K × column I, total NQI = 0.196

Column M. Nutrient contents for 100 calories raw spinach, column J × 100/23 (see row 4)

Column N. Nutrient contents per 100 calories in RDA units, column M/column B (see footnotes)

Column O. Contributions to NQI per 100 calories, column N × column I, total NQI = 0.852

\* Vitamin K and lutein + zeaxanthin are truncated to 1.150 RDAs per 100 g (equivalent to 5 RDAs per 100 calories). These values before truncation were 5.37 and 6.10, respectively.

\*\* Vitamin K and lutein + zeaxanthin are truncated to 5 RDAs per 100 calories. These values before truncation were 23.33 and 26.52, respectively.

The NQI per serving of 1 cup raw spinach (30 g) can be most easily calculated directly from the NQI per 100 g, using the USDA serving size:

$$\text{NQI per serving} = (0.196/100 \text{ g}) \times (30 \text{ g/serving}) = 0.059/\text{serving}$$

The NQI per 1 cup serving can also be calculated in the same detailed way as the other NQIs shown here, using nutrient contents for 30 g of spinach. In this case, the contents of vitamin K and lutein + zeaxanthin are truncated to 0.345 RDAs per 30 g (equivalent to 5 RDAs per 100 calories).

In practice, only the NQI per 100 g need be calculated with the detail shown here, after first also calculating columns M and N for 100 calories of food, and truncating any values greater than 5 in column N and equivalently truncating the corresponding nutrients in column K. (Truncation is needed almost exclusively for dark green vegetables and liver.)

Then, in this case for raw spinach,

$$\text{NQI per 100 calories} = 0.196/100 \text{ g} \times (100 \text{ g}/23 \text{ calories}) = 0.852/100 \text{ calories}$$

$$\text{NQI per serving} = (0.196/100 \text{ g}) \times (30 \text{ g/serving}) = 0.059/\text{serving}$$

## COMPARISON OF INDEX WEIGHTS FOR WOMEN AND MEN, AGE 19-30

The following table shows the many differences in key parts of the calculation of index weights for U.S. women and men of the same age, 19 to 30. Note the especially large differences for iron.

27 NUTRIENTS & CALORIES	INDEX CALCULATION FOR WOMEN				INDEX CALCULATION FOR MEN			
	RDA	INTAKE	DEFIC.	INDEX WT.	RDA	INTAKE	DEFIC.	INDEX WT.
Calories	2200				2900			
Vitamin A	700	607	1.15	0.024	900	615	1.46	0.028
Vitamin D	15	4.6	3.26	0.069	15	4.6	3.26	0.063
Vitamin E	15	7.2	2.08	0.044	15	8.1	1.85	0.036
Vitamin K	90	88.9	1.01	0.021	120	88.9	1.35	0.026
Vitamin B-6	1.3	1.91	0.68	0.014	1.3	2.36	0.55	0.011
Vitamin B-12	2.4	5.19	0.46	0.010	2.4	6.41	0.37	0.007
Vitamin C	75	84.2	0.89	0.019	90	116.2	0.77	0.015
Folate	400	527	0.76	0.016	400	696	0.57	0.011
Niacin	14	23.9	0.59	0.012	16	29.4	0.54	0.010
Riboflavin	1.1	2.16	0.51	0.011	1.3	2.55	0.51	0.010
Thiamin	1.1	1.59	0.69	0.015	1.2	2.01	0.60	0.011
Calcium	1000	946	1.06	0.022	1000	946	1.06	0.020
Potassium	4700	2509	1.87	0.039	4700	2509	1.87	0.036
Magnesium	310	277	1.12	0.024	400	328	1.22	0.023
Phosphorus	700	1297	0.54	0.011	700	1658	0.42	0.008
Copper	0.9	1.3	0.69	0.015	0.9	1.59	0.57	0.011
Iron	18	14.7	1.22	0.026	8	19.2	0.42	0.008
Selenium	55	104.9	0.52	0.011	55	131	0.42	0.008
Zinc	8	11.6	0.69	0.015	11	14.5	0.76	0.015
Choline	425	305	1.39	0.029	550	305	1.80	0.035
Fiber	25	15.2	1.64	0.144	38	15.2	2.50	0.200
Linoleic acid	12	14.5	0.83	0.036	17	14.5	1.17	0.047
alpha-Linolenic acid	1.1	1.4	0.79	0.034	1.6	1.4	1.14	0.046
Protein	46	76.2	0.60	0.085	56	91.5	0.61	0.078
Lutein+Zeaxanthin	2000	1362	1.47	0.064	2000	1022	1.96	0.078
Lycopene	10000	5219	1.92	0.050	10000	7886	1.27	0.030
ORAC (total)	20000	10000	2.00	0.140	20000	10000	2.00	0.128
TOTALS				1.000				1.000

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