July 15, 2025

Comments on a Proposed Rule Issued by the FDA: "Food Labeling: Front-of-Package Nutrition Information"

Docket No. FDA-2016-2024-N-2910

Submitted By: Heartland Health Research Alliance and the Swette Center for Sustainable Food Systems at Arizona State University

These comments are in response to the January 16, 2025 "Proposed Rule" issued by the FDA governing the content of front-of-package (FOP) nutrition information (Fed. Reg. 5426-5463).

HHRA is a non-profit organization that conducts research on the impacts of farming systems and technology on food safety, food nutritional quality, and public health (hh-ra.org). HHRA is currently conducting the Heartland Study, a large, multi-center birth cohort study in the Midwest focused on the impacts of prenatal and early life pesticide exposure. The Swette Center conducts transdisciplinary research and education on food system transformation for social progress, economic productivity, and environmental resiliency (sustainability-innovation.asu.edu/food/).

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HHRA and the Swette Center submitted detailed comments to the FDA in February, 2023 in response to an earlier request for public comments on the definition of "healthy" food. In those comments, we recommended adoption of novel metrics to quantify food nutritional quality as part of an analytical system called NuCal.

Advantages inherent in NuCal, or similar systems designed to quantify the nutritional quality of food are described more fully in a paper published in *Foods* entitled "Enhanced Labeling to Promote Consumption of Nutrient Dense Foods and Healthier Diets" (Benbrook and Mesnage, October 24, 2024). This open-access paper appears in Appendix B. The comments offered herein draw upon HHRA's 2023 comments and the 2024 paper in *Foods*.

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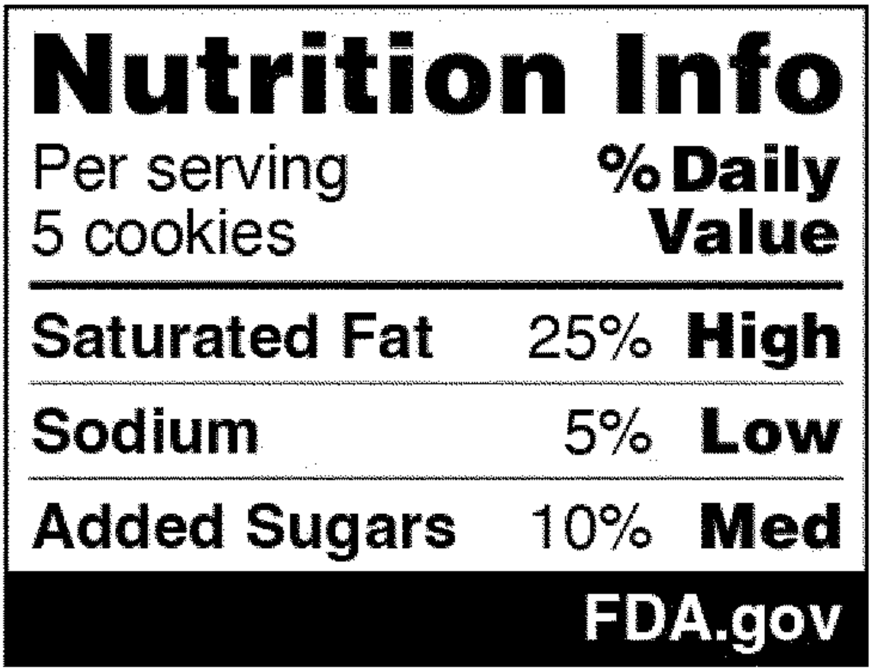
I. Summary of Comments and Recommendations

We strongly support the need for clearer and more actionable front-of-package (FOP) information on the nutritional quality of food. We agree with the FDA that such information should be mandatory, delivered in a standard format, and appear in roughly the same place on food packages (e.g., FOP bottom right corner).

We applaud the FDA's decision to base the nutritional information in the newly proposed FOP "Info Box" on the nutrients and ingredients in a single standard serving of a food product. ***Doing so harmonizes the delivery of nutrition-related information in a FOP Info Box with the information in back-of-pack Nutrition Fact Panels***. It also corresponds to how most consumers think about food portions and how they compare the nutritional quality and cost of one food product versus another.

The FDA is proposing a FOP Info Box like the one pasted in below that essentially restates information on fat, salt, and sugar already featured prominently in Nutrition Facts Panels.



The only additional information conveyed in the above, proposed Info Box is the qualitative descriptors **Low**, **Medium**, and **High** associated with the fat, salt, and sugar content in a serving of food. Such critical real estate on the front of food packaging should not be devoted to restating basic information on fat, salt, and sugar that is already featured in back-of-pack (BOP) Nutrition Fact Panels.

The FDA proposes a compliance date of three years. Given the pressing need for rapid progress in reversing trends in the nation's health, the FDA should move forward more quickly.

We urge the FDA to not focus new FOP nutrition labeling on just fat, salt, and sugar. Instead, ***the focus should be on the overall contribution of a serving of food in meeting a consumer's daily needs for essential, health-promoting nutrients relative to the caloric density of the serving of food***.

By incorporating nutrient content ***and*** caloric density in a single metric, new FOP labeling will guide consumers to food products that promote health because of the essential nutrients they contain, while also avoiding products with high levels of fats and sugars that drive up the number of calories per serving.

The Nature of Food Nutritional "Quality" and "Value"

In the proposed rule, FDA uses the term "nutritional value" of food. We question whether this is the optimal term of art, since use of the word "value" in this context will likely trigger some consumers to focus on comparative cost considerations, as opposed to differences in nutritional quality.

We urge the FDA to refer to the "nutritional quality" of a serving of food, instead of the serving's "nutritional value". In addition, the FDA should state clearly in multiple places that the "nutritional quality" of a serving of food refers to the degree to which the nutrients in the serving meets the essential, daily nutrient needs of an individual as specified in Recommended Dietary Allowances (RDAs) regarded as essential in sustaining health (or equivalent intake benchmarks).[1]

Currently there are around 30 macro- and micronutrients in food that are regarded as essential in sustaining good health, and for which RDAs or equivalent intake benchmarks have been set. Another half-dozen to perhaps 10 nutrients are likely also very important, if not essential for sustaining health. Some such nutrients are present just in specific food groups and are important in quantifying nutritional quality for certain foods.

As the FDA notes on page 5441 of the proposed rule, the *Dietary Guidelines, 2020-2025* identifies five "nutrients of public health concern" – fiber, vitamin D, calcium, iron, and

[1] Several terms are used by different governments and entities that are functionally equivalent to RDAs. These include Reference Intakes and acceptable daily intakes.

potassium.[2] These are among the essential nutrients that should be included in the method the FDA adopts to quantify the nutritional quality of food.

Simple and Compelling Nutritional Information

The FDA discusses in several places the difficulty some consumers have in understanding the nutrition information currently on food packages. FDA stresses the need for a FOP Info Box that is simple and easy to interpret. We agree with such an aspiration.

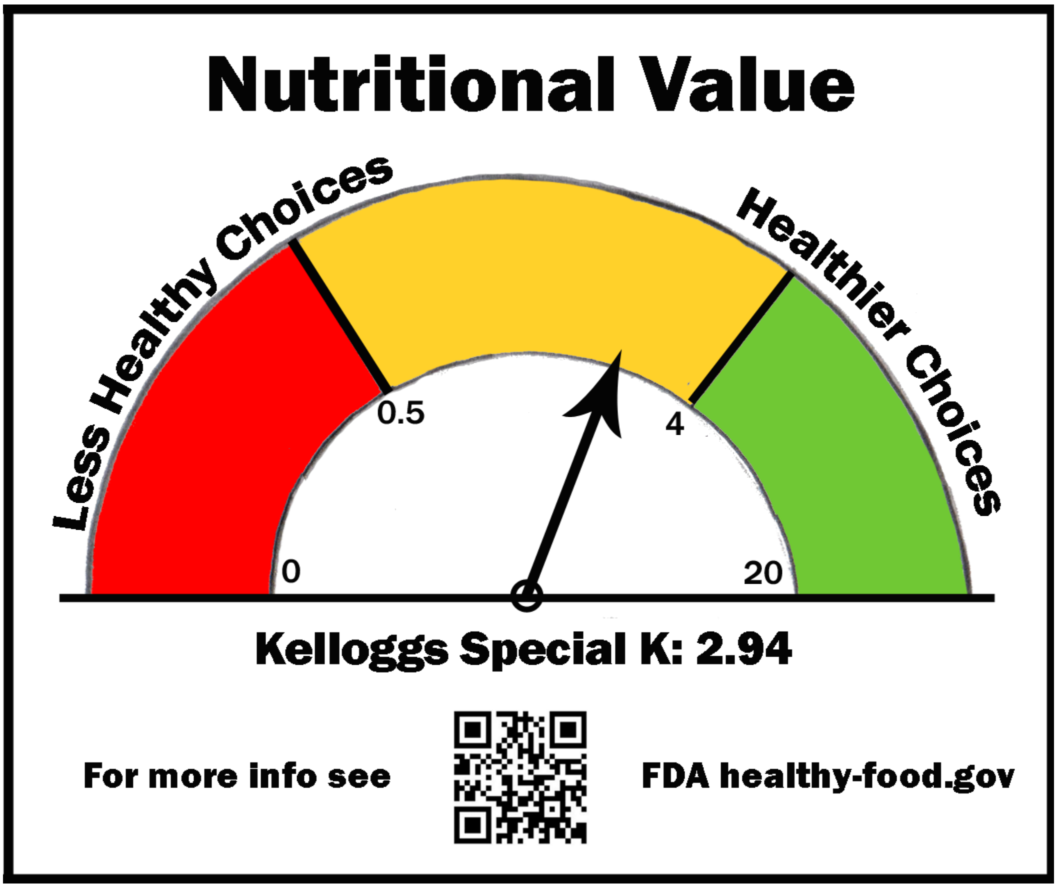
We urge the FDA to adopt a data-driven, nutritional quality metric like the core NuCal system metric described in these comments, as well as in HHRA's February 2023 comments to the FDA. The NuCal metric takes into account both the nutritional quality of a serving of food in terms of meeting a person's daily needs, as well as the caloric density of the serving of food.

The NuCal metric will promote reducing the calories in a serving of food stemming from fat and sugar (the primary goal addressed in the FOP Info Box proposed by the FDA), while ***also providing consumers much needed guidance in identifying foods that provide significant amounts of health-promoting nutrients***.

Appendix A presents the NuCal values for 196 foods in a table that is organized according to three zones along a food nutritional quality continuum. The second to last column in the table in Appendix A is labeled "Nutritional Quality Contribution" and is the core NuCal metric. An example appears below of a graphic showing how the NuCal metric for Kellogg's Special K cereal could be conveyed in a simple, FOP Info Box. In section three of our comments, tables appear highlighting some of the foods that would land in the three zones along the food nutritional quality continuum based on NuCal metric values per serving.

The graphic below is adapted from the gauge-like displays contained in HHRA's 2023 comments to the FDA and the 2025 NuCal system paper by Benbrook and Mesnage in *Foods*. This graphic depiction of the nutritional quality of a serving of Kellogg's Special K cereal matches, to the extent possible, the format and design features in the FDA's proposed Info Box that focuses on fat, salt, and sugar:

[2] The need for substantive changes in the review and revision of the Dietary Guidelines is addressed succinctly in Mozaffarian (2025). "The 2025-2030 Dietary Guidelines – Time for Real Progress," JAMA.



The above graphic element provides much more, and different information compared to the FDA's proposed Info Box. The use of any such graphic in FOP Info Boxes would be accompanied by a whole-of-government educational campaign to explain to consumers how to interpret the information in the graphic elements appearing in the boxes.

By clicking on the QR code in a FOP Info Box, or by visiting FDA's "healthy" food website, consumers and other interested parties could access detailed information on the science and data supporting the contents of a graphic. They could also access other web-based information highlighting healthier food choices within a food category, or in a different category of food products.

Consumers paying attention to nutritional quality will soon learn how to quickly place into perspective where a given food choice, or a given brand within a food group, lands along the continuum of foods from healthy to unhealthy.

A gauge-like graphic icon can convey the significant differences that exist in the nutritional quality of different foods, and do so clearly with just a glance. It can also drive home ***how much more healthy a "heathy" food choice is compared to an unhealthy food***. Such a metric also has beneficial applications in the growing number of promising "food as medicine" programs. Such programs need better tools to select the foods to prescribe in order to constructively address an individual's specific diet-health challenges.[3]

[3] See insights gained via Rosnos et al. (2025). "The effectiveness of Recipe4Health: A quasi-experimental evaluation," AJPM, Vol. 68, Issue 2.

Such a simple graphic can be compelling, especially if it does not shy away from accurately conveying the enormous differences in the health-promoting capacity of a serving of highly nutritious foods versus foods largely devoid of nutrients but laden with calories as a result of added fats and/or sugar.[4]

New FOP Info Boxes that contain such a graphic will create strong incentives for food manufacturers to change recipes and processing methods in ways that would move a food product currently in the "**less healthy**" zone into the intermediate zone, or a product in the intermediate zone into the "**healthy**" zone.

The degree of pressure on major players in the food industry to reformulate highly processed foods to make them more nutritious will be driven by the ***clarity of the information conveyed in new FOP Info Boxes***. We believe the real potential stemming from FDA's new definition of healthy food, and new FOP nutritional information "boxes", lies in motivating food manufacturers to change recipes and processing methods in ways that will benefit ***ALL*** consumers, not just the small percent of people that decide to switch to other brands that are nutritionally superior, according to FDA's new Info Boxes.

This is also why the FDA should err on the side of simplicity and frankness in conveying the enormous difference between junk food that is nearly, or fully devoid of nutritional quality, compared to the many food options that deliver substantial nutrients relative to the caloric space they take up in a person's daily diet.

The long-term economic benefits to the nation via reduced health care costs and lessened morbidity would ***dwarf the cost of implementing a system like NuCal. We believe it would constitute the boldest and most meaningful commitment to improving the quality of the US food supply ever undertaken by the U.S. government***.[5]

But none of this will happen if the FDA remains unable to rebuff the inevitable and intense political pressure the food industry and commodity associations will exert in an effort to sustain the status quo.

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[4] An important paper conveys the results of an analysis of 50,000 food products using a nutritional-quality metric similar to NuCal. The paper concludes, among other things, that calorically dense, ultraprocessed foods provide calories to consumers at lower cost compared to more nutritious options. See Ravandi et al. (2025). "Prevalence of processed foods in major US grocery stores," *Nature Food*.

[5] The economics of food as medicine programs will continue to be controversial because of the unknown, hard-to-quantify benefits stemming from preventing a person from starting to move along the metabolic syndrome pathway, or slowing progression along the pathway. The costs of most readily available alternative, GLP-1 medications, is much easier to project.

II. Shortcomings in the Currently Proposed FOP Info Boxes

We agree with the general goals outlined by the FDA in the proposed rule:

> "[Providing consumers]...interpretive nutrition information that can help them quickly and easily identify how foods can be a part healthy diet."
>
> "FDA, as part of a whole-of-government approach, broadly seeks to help reduce the burden of diet-related chronic diseases. We are committed to accomplishing this goal by, in part, prioritizing nutrition initiatives that can help improve dietary patterns in the United States."

However, we conclude that the content of the information the FDA is currently proposing will not optimally assist consumers in making food choices consistent with attainment of the FDA's core goal – ***promoting positive health outcomes for all Americans***.

For this reason, we recommend alternative content for inclusion in FOP Info Boxes. Such information will help far more people attain and retain good health, and also promote healthy pregnancies that avoid diet-driven and epigenetic disruptions that can increase developmental deficits and the frequency and severity of adult-onset disease.

A. Deficiencies in the FDA's Proposal

The need for alternate information within FOP Info Boxes arises from several deficiencies in the content the FDA is proposing for inclusion in FOP Info Boxes.

First, the proposed content focuses on just three macronutrients in food – fat, salt, and sugar. There is no mention of the many other nutrients and compounds in food products that also significantly influence health outcomes.

Second, there is no scientific justification for singling out "saturated fat" as a universally negative component in food. All fats are not created equal.[6] Many fatty acids perform essential functions in a vast array of cellular and metabolic processes that underpin human health. Some saturated fatty acids are now regarded as heart-health neutral, or even positive. By casting aspersions on all saturated fats, the proposed FOP Info Boxes will pass along misinformation that overshadows the questionable, and in any event, modest value of the added qualitative descriptor "High" included in the info Boxes.

[6] For a review, see Magkos et al. (2020(. "JACC State-of-the-Art Review: Saturated Fats and health: Reassessment and Proposal for Food-Based Recommendations," JACC.

Third, the focus on fat, salt, and sugar is clearly predicated on a desire to help consumers steer clear of the health complications arising from metabolic syndrome. Close to two-thirds of American adults are currently dealing with one or more of the markers of metabolic syndrome. Most are aware of the important role that fat, salt, and sugar play in metabolic syndrome. The content of fat, salt, and sugar in foods already receives by far more attention than all other nutrients and food components combined.

As proposed, FDA's Nutritional Info Boxes would do a poor job of addressing the needs of Americans already dealing with chronic disease, while offering next to nothing to those people seeking to retain good health via consumption of healthy food and healthy life-style choices. In general, good health is relatively simple to sustain, but difficult to restore once compromised.

The Congress passed the 1996 Food Quality Protection Act in order to direct the EPA to focus more attention on the unique pesticide-dietary risks facing pregnant women, infants and children. For the same reasons in crafting the nutrition information featured in new FOP Info Boxes, the FDA should assure the nutritional needs of pregnant women, infants, and children are addressed and advanced.[7] The FDA can do so by placing considerable emphasis on the nutritional needs of pregnant women and young Americans for whom ***health promotion through consumption of nutrient dense food is surely the best medicine***.

Fourth, the prevalence of metabolic syndrome across the U.S. population has steadily increased despite the whole-of-government and private sector efforts over the last 30 years to educate consumers about the role of fat, salt, and sugar in triggering and worsening metabolic syndrome.

This begs the question – Is there something about the design and information in the proposed FOP Info Boxes that will flip a switch in a significant share of consumers and motivate them to alter their food choices? We highly doubt that this will be the case, and thus urge the FDA to reconsider the nutrition-health information conveyed in FOP Info Boxes.

Fifth and as proposed, FOP Info Boxes are designed to bring about improvements in public health primarily among one segment of the population: those adults approaching or progressing along the metabolic syndrome spectrum. But even for people dealing with metabolic syndrome, excessive and/or inadequate intakes of other nutrients and constituents in food are likely contributing in significant ways to health outcomes.

[7] The compelling science supporting renewed focus by FDA on reproduction and children's health is summarized in Marshall et al. (2022). "The importance of nutrition in pregnancy and lactation: lifelong consequences," *Am J Obstet Gyncol*.

As highlighted above, the unique needs of women prior to and during pregnancy, as well as postnatally, warrant much more attention, as do the needs of infants and children. In fact, multiple studies conclude that the greatest return on investments in health promotion and disease prevention arise when focused on reproduction and children's development.

The deeply worrisome trends in overweight, diabetes, and fatty liver disease among children and adolescents is a ***flashing, ominous sign of major trouble in the years ahead, and markedly higher health-care costs and morbidity***.

There are indisputable connections between unhealthy food, rising government health care expenditures, and lost tax revenues when chronic disease and disability impairs an individual's ability to constructively contribute to GNP through retirement.[8] These connections are why the ***outcome of this FDA food nutritional quality rulemaking will likely be one of the most consequential drivers of the future fiscal health of the nation***. Failure to turn the tide will lead to an unprecedented fiscal crisis for the nation as health-care costs rise and tax revenues fall.

Sixth, for decades there has been substantial investment capital flowing into R&D and drug development targeting the discovery and commercialization of medications to forestall metabolic syndrome, slow its progression, and/or curtail the severity of sequelae. To date, the GLP-1s are the most significant advance to come from such investments, and several more promising therapeutic medications are expected to emerge in the next one to two decades.

But there are no comparably effective pharmaceutical interventions for many other serious public-health problems rooted in poor food quality and less-than-optimal dietary patterns.

Americans in the last third of their life-cycle are the beneficiaries of the majority of drug research and health care spending. In order to remain healthy, those in the first one-third of life are largely dependent on access to healthy food and well-balanced diets, coupled with sound lifestyle choices and a measure of good luck. The FDA's proposal does little to help this segment of the population remain healthy as individuals grow into adulthood.

Seventh, the descriptors "**Low**", "**Med**", and "**High**" are ambiguous and inherently subjective. What is "**Low**" or "**High**" for one person, might be "**Mod**" for other individuals. These descriptors only make sense relative to defined benchmarks, which the average consumer won't be aware of.

Setting descriptor benchmarks will force FDA scientists to explain and defend the indefensible. Food companies and commodity organizations that disagree with where the FDA draws the lines demarcating "**Low**" from "**Mod**" and "**Mod**" from "**High**" will have an easy time in the administrative appeal process, or in court, in pointing out the shortcomings of such

[8] Suboptimal nutrition contributes to, and can accelerate mental decline during aging. Slowing the loss of mental acuity via healthier foods and dietary patterns is another key area in need of greater focus by FDA in the context of food nutritional quality Info Boxes. See Tessier et al. (2025). "Optimal dietary patterns for healthy aging," *Nature Medicine*.

benchmarks, notwithstanding the merit of the "interpretive judgements" reached by the FDA. As a result, the FDA can expect a nearly endless series of administrative and court orders requiring it to add various caveats and exceptions.

Far before this process comes to closure, what started out as a purportedly clear and simple scheme will become muddled. And as the media covers various successful challenges to the FDA's proposed benchmarks, the public will understandably become confused and skeptical about the meaning and reliability of the descriptors.

Eighth, the content of phytochemicals, minerals, and other micronutrients in food plays a vital and essential role in human health, notably in reproduction, children's development, the functioning of the immune system, and neurological health and decline.[9] Moreover, the adequacy of intakes of some two-dozen essential nutrients interact in complex ways with fat, salt, and sugar intakes in driving the severity of complications arising from common health challenges ranging from an ear infection to a bout of food poisoning, an autoimmune disease, cancer, or mental illness.

Micronutrient intakes also can play vital roles in mitigating longer-term, adverse health outcomes triggered by epigenetic impacts during fetal development, or as a child matures. More specifically, adequate and balanced micronutrient intakes can augment and reinforce effective immune and metabolic responses due to exposure to pesticides in food, bacterial or viral pathogens, food additives, medications, and pollution.

For some people, improving intakes of micronutrients, especially early in life, can do more to restore health, or slow the progression of disease, than interventions targeting fat, salt, and sugar and prevention of metabolic syndrome.

And ninth, current nutritional-quality information on food packaging, in point-of-purchase information, in marketing and media stories about food and health, and delivered through other channels is too often exaggerated, confusing and/or conflicting, and is not backed up by sound science.

The current, unfortunate mix of misleading and just-plain-bad information on micronutrients, and other naturally-occurring compounds in the human diet (e.g. phytochemicals), has created a foggy mist that both obscures their importance and undermines efforts by consumers to make smarter food choices.

A more assertive role by the FDA in emphasizing the critical role of adequate and balanced intakes of micronutrients and phytochemicals will be essential in unlocking the public health benefits attainable through heightened focus on the health-promoting roles of micronutrients.

[9] See for example, Kaplan et al. (2022). "The effect of a high-polyphenol Mediterranean diet (Green-MED) combined with physical activity on age-related brain atrophy: the Dietary Intervention Randomized Controlled Trial Polyphenols Unprocessed Study (DIRECT-PLUS)," *AJCN*.

We conclude that the FDA should take a key step in this direction through reconsideration of the nutritional-quality information featured in FOP Info Boxes.

The FDA goes on to state that:

> "...we have tentatively determined that an interpretive FOP nutrition label is needed to help consumers readily observe and comprehend information about certain nutrient attributes of a food at the point of decision-making...that will assist them in maintaining healthy dietary practices."

Clearly, the proposed focus on "certain interpretive attributes" in food products is conceptually inconsistent with the whole-of-government focus on heathy dietary patterns. Nearly everyone agrees that no one food, or nutrient, or set of nutrients, renders a specific food healthy or not, nor a diet healthy or not. Yet by proposing to focus only on fat, salt, and sugar in FOP Info Boxes, the FDA undermines its efforts to convince consumers to think broadly about the nutritional adequacy of their overall food and dietary choices.

Moreover, it is folly to expect consumers to forego UPFs entirely. For this reason, the FDA's Info Boxes should help consumers couple a serving of junk food with one or two servings of nutrient-dense, healthy foods that score high along the nutritional value continuum.

This sort of simple rule of thumb, if communicated often and consistently, could provide consumers with the type of clear interpretive guidance regarding daily food choices essential to advance public health and lessen health care costs via improvements in the nutritional quality of the U.S. food supply.

B. What Constitutes the "Nutritional Value" of a Food Product

In the proposed rule, the FDA writes that federal law:

> "...authorizes FDA to require the declaration of other nutrients [other than saturated fat and salt] if we determine that the declaration [on labeling] will provide information regarding the nutritional value of such food that will assist consumers in maintaining healthy dietary practices."

For reasons stressed in these comments, we conclude that information on the concentration of micronutrients is highly relevant to the "nutritional value" of food products. However, it is not appropriate, and indeed can be counterproductive, to focus on just one or a few micronutrients, just as it is counterproductive to emphasize just fat intake, or sugar or just salt intake in mitigating metabolic syndrome.

For good reason, the FDA has focused in recent years on dietary patterns. But the science and logic supporting such focus applies equally to the mix, levels, and adequacy of micronutrients/phytonutrients in a serving of one food compared to other foods.

Governments around the world have identified some two-dozen micronutrients that are essential for good health and must be obtained from food and/or supplements. The FDA has established RDAs for around two-dozen micronutrients. In the balance of these comments, we use “RDA” to refer to recommended daily intake levels needed to sustain good health.

Different food groups contain different mixes of nutrients. Each food group is an especially important source of a few to a half-dozen nutrients, while others are just moderate in only a few. About one-half of the U.S. food supply is largely devoid of any essential nutrients.

The health-promoting nutrients and compounds in fruits and vegetables vary markedly in contrast to grain-based foods and animal products. The nutrient composition of fish varies substantially from all other food groups. Multi-ingredient foods contain complex mixtures of essential nutrients derived from the individual ingredients called for in recipes. Specific foods within a food group sometimes offer markedly more nutrients at lower caloric cost compared to many other foods within the same group. ***Such differences matter, and the FDA’s new FOP Info Box system should aspire to reflect such differences to the full extent possible***.

The diversity and complexity of the nutrient profiles in different foods is why the food and nutrition sciences are so challenging. It also vastly complicates the challenges facing the FDA, and any other entity, in communicating to consumers the “nutritional value” of one food product compared to others via the content featured in a simple and limited FOP Info Box.

As argued in HHRA’s comments submitted to the FDA in February 2023 on how to define and quantify “healthy” food, we believe that the best approximation of the “nutritional value” of a food product should be grounded in the degree to which a serving of food meets an individual’s daily nutritional needs, relative to the percent of that person’s caloric space taken up on any given day by the serving of food.

The percent of daily nutrient needs met via ingestion of a serving food relative to the percent of caloric space taken up is the core metric in the NuCal system.

Healthy foods deliver a several-fold greater share of a person’s nutrient needs compared to the caloric space a serving occupies. Unhealthy foods do the opposite; they take up a several-fold higher percentage of caloric space relative to the percentage of nutrient needs satisfied.

The core NuCal metric doubles down on nutrient density by taking into account both the concentration of nutrients in a serving of food, ***and*** the number of calories in one serving. By combining these two, important measures of nutrient density in a dimensionless metric***, a numeric scale is created that is easy to interpret and convey graphically in a simple and compelling way***.

C. Advancing the Effectiveness of Food as Medicine Programs

Published research has confirmed the great promise of food as medicine programs that combine medical interventions with nutritional education and access to nutrient-dense foods.[10] But as many groups administering food as medicine programs are learning, the selection of foods to prescribe and promote need to vary markedly based on the specific health needs of individual patients.

The selection of foods to promote via food as medicine programs should ideally vary by stage of life, health status, and other factors contributing to adverse health outcomes. Pregnant women are typically deficient in a different set of nutrients compared to most other population cohorts. People dealing primarily with health problems rooted in inflammation will respond most quickly to diets high in anti-inflammatory polyphenols. Likewise, those with an autoimmune disease may have unique dietary needs, as do those with digestive disorders. This pattern generally holds across the diversity of health conditions, diseases, genetic anomalies, and accidents that contribute to morbidity.

Major steps can be made in customizing food as medicine prescriptions by altering the nutrients included in a NuCal-like nutritional quality algorithm, coupled with altering the weights assigned to specific nutrients. Over the next 10-20 years, there will surely be new data and refined systems that can generate disease- and health-status specific food nutritional quality scores for use in making specific food prescriptions for individual patients within the context of food as medicine programs.

[10] Defraeye et al. (2025). "Advances in Food-as-Medicine interventions and their impact on future food production, processing, and supply chains," *Adv, Nutrition*.

III. The NuCal System

The NuCal system metric, or one similar to it, can be computed for any food product, including multi-ingredient foods and entire meals, through use of a nutrient profiling system. The essential steps in doing so will be the same for foods in all food groups, but minor differences will be needed in the nutrients included in the algorithm across food groups.

For example, fruits and vegetables generally do not contain health-promoting omega 3 fatty acids, and animal products generally do not contain Vitamin C and most plant polyphenols. But in general, the steps required to quantify the nutritional value of a serving of food using the NuCal metric entail:

- Selecting the set of nutrients essential in promoting and sustaining good health to include in the calculations for each food group;
- Identifying the appropriate RDA for each of these nutrients;
- Measuring the amount of each nutrient in one serving of food;
- Calculating the degree to which the level of a nutrient in a serving of food meets, or exceeds, the RDA, and then repeating this step across all selected nutrients;
- Computing the total contribution of a serving of food in meeting nutrient needs by adding together the computed ratios across all selected nutrients, producing a "Nutritional Quality" score for a serving of a given food;
- Calculating the percentage of a typical daily allotment of 2,000 calories taken up by the serving of a given food; and
- Dividing the Nutritional Quality score by the percent of caloric space taken up by the serving.

There are a number of technical details that have to be addressed and resolved in making the above calculations (see discussion of several in the Benbrook and Mesnage paper in Appendix B). For example, when a serving of a food is very high in one nutrient, should the Nutritional Quality score for that one nutrient-food combination be truncated at one RDA, or two, or four? Should nutrients added in a recipe via supplements count, and if so how?

Should nutrients that are often significantly deficient in the American diet be weighted more heavily in computing a food's Nutritional Quality score, and vice versa?

Fiber is an example of a key, health-promoting nutrient that warrants special focus by the FDA. There is near-universal agreement that intakes are seriously deficient among most Americans. Higher intakes would improve public health trajectories, yet fiber is not addressed in the newly proposed FOP Info Boxes. We urge FDA to devise a way to also alert consumers to fiber-rich food products in FOP Info Boxes and/or via other means.

The core NuCal metric is a ratio:

> (Percent of total essential nutrient needs met in a day from the nutrients in one serving of food) divided by (Percent of the daily caloric space taken up by the serving of food)

The cumulative percentage in the numerator across some 24-36 essential nutrients would come from the FDA's nutrient profiling system. The higher this percentage, the more nutrient needs satisfied by a single serving of a given food on any given day.

The denominator is the caloric content of a single serving of food, from the back-of-pack Nutrition Facts panel, divided by the typical 2,000 calories per day diet regarded as generally sufficient for most adults.

Calculating NuCal values makes it possible to form a bridge between the information conveyed in FOP Info Boxes and the information and messaging in back-of-package Nutrition Facts panels. The table in Appendix A provides NuCal metric values for 196 foods; the NuCal value is in the second column from the right of the table (labeled "Nutritional Contribution Metric"). The foods are ranked in the table by NuCal value from highest to lowest. A value of just over 17 for raw spinach and boiled turnip greens are the two highest among the 196 foods; the lowest scoring are sugar-based drinks that are essentially devoid of nutrients.

The 196 foods include dozens of single-ingredient fresh, whole foods, multiple versions of common and widely consumed foods like milk (whole, 2%, 1%) and bread (white and enriched, whole grain), cereals, common meals or center-of-plate options (a burger and fries, slice of pizza, fish and chips). The Nutritional Quality Index (NQI) is the nutrient profiling system used in the calculations. It was developed by Benbrook and Davis as part of work carried out for The Organic Center.

A. Steps Required for FDA to Compute NuCal or Similar Values

Computing NuCal scores for the ~50,000 common items sold at retail will require additional nutrient-content testing. Presumably, the FDA would issue guidelines explaining the data that must be generated per serving of a given food product and companies would be required to generate such data and upload it into an FDA website where the nutrient profiling algorithm would be accessible.

The added cost of calculating NuCal values for a given brand-name product would account for a tiny fraction of the annual advertising budget for the vast majority of national brands. The value derived from generating such data would extend beyond supporting FDA nutritional value computations and supporting the content in FOP Info Boxes. Such data would also support more sophisticated, food quality-health outcome epidemiological modeling. It would advance studies of changes in the nutrient content of food brought about by plant breeding and farming system changes. It would also support more accurate quantification of the impacts of processing and manufacturing on the nutritional value of food as sold to consumers.

Ideally, the FDA and USDA would collaborate in a whole-of-government and private sector initiative to create the food-product-specific nutrient content databases required to compute NuCal-like metrics. Federal agency roles would include promoting data quality and homogeneity, and assuring accessibility to such data. These steps will allow a diversity of people and entities to carry out analytical work helpful in more fully understanding the nutritional quality of a given food product. It will help identify factors undermining food nutritional quality, such as industrial farming methods and excessive processing, as well as steps to enhance nutritional quality, like enhancing soil health and embracing minimal-processing techniques.

The NuCal system relies upon a food's Nutritional Quality Index (NQI) score per serving. The NQI used to calculate the values in the 196 foods in Appendix A is composed of 27 nutrients: eleven vitamins, eight minerals, protein, fiber, antioxidant activity as measured by total ORAC, lutein + zeaxanthin, linoleic acid, linolenic acid, lycopene, and choline, all of which have been demonstrated to offer significant health benefits.

RDA-equivalent values and serving sizes are taken from US government guidance documents, or recommended levels of intake advanced by other countries or organizations with expertise in food and nutritional science.

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

The nutritional quality scores generated by the NQI are similar to those produced by other nutrient profiling systems that contain roughly the same set of nutrients. While the FDA will need to address and resolve many computation details in developing its version of a nutrient profiling system, the ultimate ratings the FDA's system will generate will likely track those from the NQI, Food Compass, and other similar systems.

A significant enhancement in the NuCal system metric, in contrast to the NQI value alone, is the weight placed on the caloric content of a serving of food.

B. Establishing Zones Along the NuCal System Continuum

There is no one correct way to delineate the green-yellow-red zones along a nutritional quality continuum. Such a continuum should clearly distinguish between nutrient-rich versus nutrient-deficient foods. The core message to consumers is then simple—look for options that reflect healthier choices, i.e. foods that score closer to, or deeper within the green zone along the nutritional-quality continuum, while avoiding/minimizing red-zone foods.

In the graphic advanced in section one in these comments, we set the threshold between moderately healthy, yellow zone foods and green-zone foods at a metric value of 4, and the threshold between the yellow and red zones at 0.5.

Hence, a food at the low end of the green zone provides 8-fold or more nutritional bang for the calorie buck than a food at the top of the red zone (4 divided by 0.5).

Foods in the red zone along the continuum contain one-half or less of daily nutrient needs relative to the calories they provide. Foods in the yellow zone have NuCal system scores at or above 0.5 and less than 4.0.

Table 1 provides NuCal metric scores and rankings for 23 foods within the green zone of the NuCal system continuum. Raw spinach tops the list with a score just over 17 and is among the four foods scoring 10 or higher. These are among the nutrient-rich foods Americans should seek out and include in healthy dietary patterns, which they might do more frequently if they had access to this information

Table 1. Nutrition Contribution Values for 23 Foods in the Green Zone of the Continuum						
	NQI Value		Per Serving			Nutritional Contribution Value
	Per Serv.	% Nutrient Needs Met	Serv. Size	Calories	% Daily Caloric Need	
SPINACH,raw	0.059	5.88%	1 cup	6.9	0.35%	17.05
TURNIP,greens,boiled	0.123	12.26%	1/2 cup	14	0.72%	17.02
LETTUCE,Romaine	0.061	6.12%	1 cup	8.0	0.40%	15.32
KALE,boiled	0.138	13.83%	1/2 cup	18	0.91%	15.20
ASPARAGUS,boiled	0.088	8.76%	1/2 cup	20	0.99%	8.84
BROCCOLI,boiled	0.121	12.05%	1/2 cup	27	1.37%	8.83
BRUSSEL sprouts, boiled	0.118	11.83%	1/2 cup	28	1.40%	8.42
ONION,green tops	0.034	3.43%	1/2 cup	10	0.48%	7.14
LIVER,calf,braised	0.562	56.20%	3 oz.	164	8.20%	6.85
ARTICHOKE,boiled	0.137	13.73%	1/2 cup	45	2.23%	6.17
BELL PEPPER,green	0.046	4.55%	1/2 cup	15	0.75%	6.07
ALL-BRAN,Kellogg (fortified)	0.218	21.78%	1 ounce	74	3.69%	5.90
CELERY,raw	0.021	2.15%	1/2 cup	8.2	0.41%	5.26
LETTUCE,iceberg	0.021	2.09%	1 cup	8.0	0.40%	5.24
CARROT,boiled	0.070	7.01%	1/2 cup	27	1.37%	5.13
SQUASH,winter,baked	0.096	9.56%	1/2 cup	38	1.91%	5.01
TOMATO,red	0.041	4.05%	1/2 cup	16	0.81%	5.00
CABBAGE,green,raw	0.027	2.68%	1/2 cup	11	0.56%	4.76
CAULIFLOWER,boiled	0.034	3.40%	1/2 cup	14	0.71%	4.77
CRANBERRY,raw	0.107	10.74%	1 cup	46	2.30%	4.67
STRAWBERRY	0.106	10.58%	1 cup	49	2.43%	4.35
GREEN beans,boiled	0.047	4.66%	1/2 cup	22	1.10%	4.22
RASPBERRY	0.130	13.03%	1 cup	64	3.20%	4.08

A serving of calf's liver is the food contributing the most significant mix of essential nutrients, as reflected in the remarkable 56.2% score in the parameter "% Nutrient Needs Met." But it is also by far the most calorie-dense food, with one serving taking up 8.2% of a person's daily 2,000 calorie allotment. These two parameter values result in a NuCal system score of 6.85.

Also note that a breakfast cereal, Kellogg All-Bran, makes it into the green zone on account of nutritional supplements added to the recipe.

In the full list of 196 foods, 32 foods (16%) fall within the green zone when the threshold is set at 4.0 or above. If the green-zone threshold were lowered to two, another 18 of the 196 foods would fall within the green zone. The total of 41 green zone foods would now represent 21% of all foods arrayed along the continuum, but markedly lessen the differences between green and yellow zone foods, and green and red zone foods.

Table 2 reports NuCal values for 42 foods in the yellow zone. These foods are associated with NuCal scores between 0.5 and 4.0. Kellogg's Special K cereal has the highest score in the yellow zone in Table 2; a serving provides 15.8% of nutrient needs per the 108 calories in a single serving. Special K does not move as far along the continuum as Kellogg's All-Bran cereal. Table 1 reports that All-Bran cereal meets 21.8% of total nutrient needs via a 74 calorie serving.

Table 2. Nutrition Contribution Values for 42 Foods in the Yellow Zone of the Continuum						
	NQI Value		Per Serving			Nutritional Contribution Value
	Per Serv.	% Nutrient Needs Met	Serv. Size	Calories	% Daily Caloric Need	
SPECIAL K,Kellogg	0.158	15.83%	1 ounce	108	5.38%	2.94
PLUM	0.043	4.29%	Medium	30	1.52%	2.83
ORANGE	0.075	7.54%	Medium	62	3.08%	2.45
CHEERIOS,General Mills	0.127	12.73%	1 ounce	104	5.21%	2.44
WATERMELON	0.054	5.44%	1 cup	46	2.28%	2.39
CUCUMBER,unpeeled	0.009	0.93%	1/2 cup	7.8	0.39%	2.38
SALMON,pink,canned	0.141	14.10%	3 oz.	118	5.90%	2.39
BLUEBERRY	0.099	9.89%	1 cup	84	4.22%	2.35
GRAPEFRUIT,pink/red	0.056	5.57%	1/2 each	52	2.58%	2.16
CORN FLAKES,Kellogg	0.092	9.16%	1 ounce	103	5.13%	1.79
APRICOT	0.066	6.58%	1 cup	74	3.72%	1.77
CHERRY	0.074	7.36%	1 cup	87	4.35%	1.69
APPLE	0.055	5.50%	Medium	67	3.33%	1.65
EGG,raw	0.056	5.57%	1 large	72	3.58%	1.56
ORANGE juice,fresh	0.081	8.13%	1 cup	112	5.60%	1.45
PINEAPPLE	0.055	5.52%	1 cup	83	4.13%	1.34
MILK, 1% fat	0.068	6.82%	1 cup	102	5.12%	1.33
ORANGE juice,Frz.conc+water	0.074	7.38%	1 cup	112	5.60%	1.32
CORN POPS,Kellogg	0.072	7.22%	1 ounce	110	5.52%	1.31
MILK, 2% fat	0.068	6.84%	1 cup	122	6.10%	1.12
BEEF,rib eye,lean,broiled	0.095	9.50%	3 oz.	175	8.75%	1.09
GRAPE juice,bottled+vit.C	0.078	7.82%	1 cup	152	7.59%	1.03
POTATO, boiled in skin, peeled	0.034	3.45%	1/2 cup	68	3.39%	1.02
SHREDDED WHEAT	0.048	4.82%	1 ounce	96	4.79%	1.01
GRAPE, red and green	0.052	5.23%	1 cup	104	5.21%	1.00
MILK,whole	0.073	7.26%	1 cup	149	7.44%	0.98
OIL,soybean	0.059	5.86%	1 Tbsp.	120	6.01%	0.98
PORK, spareribs, lean+fat, roasted	0.096	9.60%	3 oz.	203	10.15%	0.95
BANANA	0.049	4.93%	Medium	105	5.25%	0.94
OATMEAL,dry	0.049	4.87%	1 ounce	108	5.38%	0.90
Pizza Hut cheese pizza	0.096	9.62%	1 slice	250	12.48%	0.77
YOGURT,plain,whole	0.055	5.49%	1 cup	149	7.47%	0.74
CHEESE,Swiss	0.039	3.87%	1 oz.	108	5.39%	0.72
BREAD,white,enriched	0.023	2.34%	1 slice	67	3.33%	0.70
BREAD,French	0.024	2.40%	1 slice	72	3.61%	0.67
RICE,brown,long grain,raw	0.034	3.37%	1 ounce	105	5.25%	0.64
BACON,cooked	0.047	4.70%	1 oz.	154	7.70%	0.61
CHICKEN,breast+wing, breaded, fried, fast food	0.079	7.90%	3 oz.	258	12.90%	0.61
RICE cake,brown rice	0.030	2.97%	2 cakes	104	5.22%	0.57
Burrito, bean & cheese	0.198	19.82%	2 each	703	35.15%	0.56
French fries, McDonalds	0.168	16.85%	Medium	616	30.78%	0.55
RAISINS,raw	0.058	5.77%	1/2 cup	218	10.91%	0.53

In the table in Appendix A listing 196 foods, 133 (68%) fall within the yellow zone. Foods near the top of the yellow zone are up to 8-fold more nutritious per calorie than a food at the bottom of the yellow zone (a NuCal value of 4 versus 0.5). Accordingly, consumers who incrementally seek out and consume foods in the upper part of the yellow zone will substantially improve the healthfulness of their diet compared to foods in the lower end of the yellow zone, or in the red zone.

Across the 42 foods in Table 2, a bean and cheese burrito delivers the greatest share of daily nutrient needs (19.8%), but would take up 35% of the caloric space in a person's daily allotment of 2,000 calories. This is why cheese-bean burritos land near the bottom of the yellow zone with a NuCal metric score of 0.56.

A serving of unpeeled cucumbers account for the lowest contribution in meeting nutrient needs among the 42 yellow zone foods in Table 2 (0.93%), but take up only 0.39% of daily caloric space. This combination of modest nutrient content, but also very few calories results in a NuCal score of 2.38, landing cucumbers near the top of foods in the yellow zone.

Table 3 covers 15 foods landing in the red zone along the continuum. In the full list of 196 foods, 31 (15.8%) land in the red zone on account of NuCal metric scores below 0.5. Such foods take up twice as much or more of the caloric space in a person's diet relative to the percentage of nutrient needs satisfied.

Table 3. Nutrition Contribution Values for 15 Foods in the Red Zone of the Continuum

	NQI Value		Per Serving			Nutritional Contribution Value
	Per Serv.	% Nutrient Needs Met	Serv. Size	Calories	% Daily Caloric Need	
COOKIE, Oreo	0.038	3.80%	3 each	159	7.97%	0.48
Chicken pot pie	0.237	23.70%	1 pie	1007	50.34%	0.47
Big Mac with cheese	0.271	27.09%	1 each	1177	58.83%	0.46
RICE, white, long grain, enr., raw	0.024	2.37%	1 ounce	104	5.18%	0.46
MARGARINE	0.007	0.68%	1 pat	31	1.57%	0.44
PIE, apple	0.056	5.56%	1 piece	296	14.81%	0.38
DONUT, glazed	0.038	3.81%	1 medium	242	12.09%	0.32
COOKIE, animal crackers	0.020	1.96%	1 oz.	127	6.33%	0.31
CREAM,whipping,heavy	0.016	1.58%	2 Tbsp	104	5.18%	0.31
CAKE, yellow, vanilla icing	0.036	3.64%	1 piece	239	11.94%	0.31
BUTTER	0.003	0.31%	1 pat	36	1.79%	0.17
GATORADE, FRUIT-FLAVORED	0.007	0.75%	20 fl. oz.	158	7.92%	0.09
HONEY	0.001	0.11%	1 Tbsp.	64	3.19%	0.04
COKE, PEPSI	0.002	0.22%	12 fl. oz.	136	6.81%	0.03
SPRITE, 7-UP	0.002	0.19%	12 fl. oz.	148	7.38%	0.03

Note that a single serving of one food in the red zone – chicken pot pie – meets 23.7% of daily nutrient needs, yet lands in the red zone because of the even bigger portion of a 2,000 calorie diet (50%). A Big Mac with cheese falls just below a chicken pot pie, meeting 27.1% of nutrient needs but taking up 58.8% of a 2,000-calorie daily allotment.

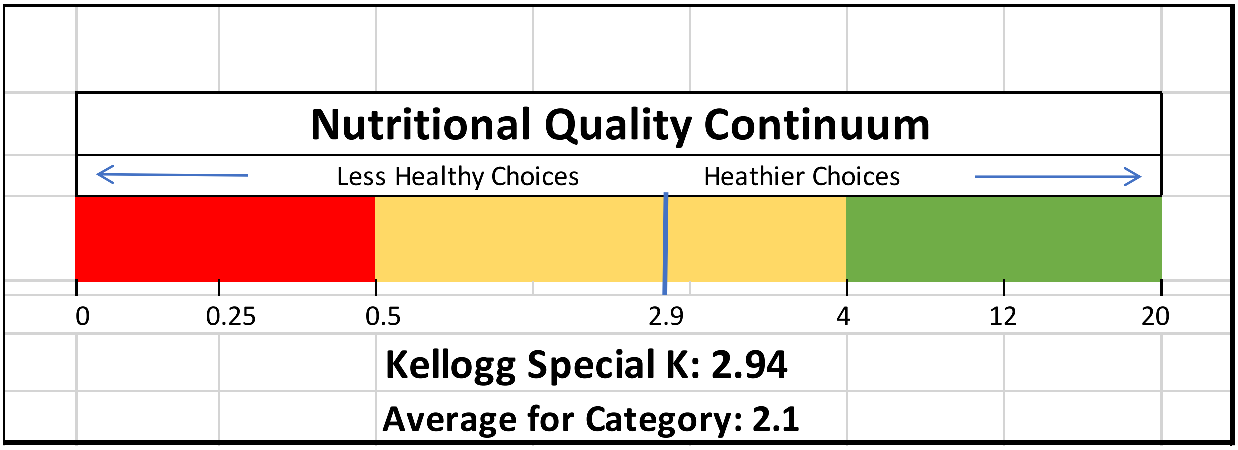
The three sugar-based beverages in Table 3 provide almost no nutritional value, yet take up 6% to almost 8% of daily caloric space. Given the number, diversity, and popularity of sugar-sweetened drinks, including some of the ways coffee is consumed, the foods and beverages in the red zone along the continuum account for a significant share of daily caloric intake.

While we have not attempted to estimate the share of total calories associated with intake of red-zone foods and beverages, we suspect the share is well over 30%. The quickest and most impactful way to improve the overall healthfulness of the American diet is to reduce the number of servings of foods that land within the red zone, while also increasing the number of daily servings of green zone foods.

Consuming a serving of orange juice with a NuCal score of 1.45 instead of a Coke or 7-Up would enhance the NuCal metric score for a single beverage serving by 48-fold!

C. The NuCal Metric Continuum

Below we provide a linear mockup of how a NuCal system continuum rating for a specific product might look like on the front of a food package, in point-of-purchase information, or on the FDA's "healthy food" website.



One of the distinct advantages of a single-metric system like NuCal that integrates nutrient content and calories per serving is the simplicity of graphically conveying differences in calorie-adjusted nutritional quality across servings of different foods and beverages.

FOP Info Box impacts will depend heavily on the clarity of the nutrition-health information conveyed by the system, coupled with the trust and confidence consumers place in the data and science supporting the system. We suspect that only the federal government can marshal the scientific and analytical resources to develop, vet, continuously improve, and keep a NuCal-like system up-to-date that covers nearly all 50,000+ food products currently sold and consumed by Americans.

The government is also the only entity that can effectively respond to all the inevitable complaints and criticisms that any meaningful FOP labeling system will generate.

The information such a system can convey would be further leveraged by making it easy for consumers to compare nutritional quality values across competing brands within a food group, and different foods across food groups. For many widely consumed food products like chips, bread, cereals, and fast-food meals, the utility of the system would be enhanced by providing an average of scores for similar products.

Today in the US, the most cost-effective option to enhance public health is improving the nutritional quality of the US food supply. By creating a FOP nutrition labeling system that guides consumers toward healthier food choices, the FDA could light a spark leading to food-industry innovation that turns unhealthy UPFs into healthier options. In this way, the FDA can help the country avoid billions in health care expenditures, while also enriching the quality of life for millions of Americans.

Appendix A. List of 196 Foods Ranked According to the NuCal System Metric

Nutritional Contribution Continuum Values for 196 Foods Based on NQI Values and Typical Serving Sizes Sizes									
Yellow = variations on the same food	Nutritional Quality Index			% Nutrient Needs Met	Per Serving		% Daily Caloric Need	Nutritional Contribution Metric	USDA Number
Rose = fortified nutrients inflate NQI	Per 100 g	Per 100 Cal.	Per Serv.		Serv. Size	Calories			
MUSTARD greens,boiled	0.129	0.859	0.090	9.02%	1/2 cup	11	0.53%	17.17	11799
SPINACH,raw	0.196	0.852	0.059	5.88%	1 cup	6.9	0.35%	17.05	11457
TURNIP,greens,boiled	0.170	0.851	0.123	12.26%	1/2 cup	14	0.72%	17.02	11569
LETTUCE,Romaine	0.130	0.766	0.061	6.12%	1 cup	8.0	0.40%	15.32	11251
KALE,boiled	0.213	0.760	0.138	13.83%	1/2 cup	18	0.91%	15.20	11234
COLLARDS,boiled	0.188	0.722	0.178	17.84%	1/2 cup	25	1.24%	14.45	11162
ENDIVE,raw	0.078	0.461	0.039	3.92%	1 cup	8.5	0.43%	9.22	11213
ASPARAGUS,boiled	0.097	0.442	0.088	8.76%	1/2 cup	20	0.99%	8.84	11012
BROCCOLI,boiled	0.155	0.441	0.121	12.05%	1/2 cup	27	1.37%	8.83	11091
SQUASH,zucchini,boiled	0.066	0.441	0.060	5.95%	1/2 cup	14	0.68%	8.82	11478
BRUSSEL sprouts,boiled	0.152	0.421	0.118	11.83%	1/2 cup	28	1.40%	8.42	11099
ONION,green tops	0.096	0.357	0.034	3.43%	1/2 cup	10	0.48%	7.14	11292
LIVER,calf,braised	0.659	0.343	0.562	56.20%	3 oz.	164	8.20%	6.85	17203
PUMPKIN,boiled	0.065	0.325	0.080	8.00%	1/2 cup	25	1.23%	6.50	11423
ARTICHOKE,boiled	0.163	0.308	0.137	13.73%	1/2 cup	45	2.23%	6.17	11008
OKRA,boiled	0.067	0.306	0.054	5.38%	1/2 cup	18	0.88%	6.12	11279
BELL PEPPER,green	0.061	0.303	0.046	4.55%	1/2 cup	15	0.75%	6.07	11333
ALL-BRAN,Kellogg	0.767	0.295	0.218	21.78%	1 ounce	74	3.69%	5.90	08001
CABBAGE,boiled	0.066	0.286	0.049	4.93%	1/2 cup	17	0.86%	5.71	11110
CELERY,boiled	0.048	0.265	0.036	3.58%	1/2 cup	14	0.68%	5.31	11144
CELERY,raw	0.042	0.263	0.021	2.15%	1/2 cup	8.2	0.41%	5.26	11143
LETTUCE,iceberg	0.037	0.262	0.021	2.09%	1 cup	8.0	0.40%	5.24	11252
CARROT,boiled	0.090	0.257	0.070	7.01%	1/2 cup	27	1.37%	5.13	11125
SQUASH,winter,baked	0.093	0.251	0.096	9.56%	1/2 cup	38	1.91%	5.01	11644
TOMATO,red	0.045	0.250	0.041	4.05%	1/2 cup	16	0.81%	5.00	11529
CABBAGE,green,raw	0.060	0.238	0.027	2.68%	1/2 cup	11	0.56%	4.76	11109
CAULIFLOWER,boiled	0.054	0.236	0.034	3.40%	1/2 cup	14	0.71%	4.77	11136
CRANBERRY,raw	0.107	0.233	0.107	10.74%	1 cup	46	2.30%	4.67	09078
RADISH,red	0.037	0.229	0.021	2.12%	1/2 cup	9.3	0.46%	4.56	11429
STRAWBERRY	0.070	0.218	0.106	10.58%	1 cup	49	2.43%	4.35	09316
GREEN beans,boiled	0.074	0.211	0.047	4.66%	1/2 cup	22	1.10%	4.22	11053
RASPBERRY	0.106	0.204	0.130	13.03%	1 cup	64	3.20%	4.08	09302

Beginning of the Yellow Zone Along the Nutrition Contribution Continuum									
MUSHROOM,boiled	0.055	0.197	0.043	4.29%	1/2 cup	22	1.09%	3.93	11261
SPECIAL K,Kellogg	0.557	0.147	0.158	15.83%	1 ounce	108	5.38%	2.94	08067
PLUM	0.065	0.141	0.043	4.29%	Medium	30	1.52%	2.83	09279
WHEATIES,General Mills	0.488	0.141	0.139	13.85%	1 ounce	99	4.93%	2.81	08089
CUCUMBER,peeled	0.016	0.134	0.011	1.08%	1/2 cup	8.0	0.40%	2.68	11206
KIWI,peeled	0.080	0.131	0.143	14.34%	1 cup	110	5.49%	2.61	09148
PAPAYA, red fleshed	0.053	0.123	0.077	7.68%	1 cup	62	3.12%	2.46	09226
ORANGE	0.058	0.122	0.075	7.54%	Medium	62	3.08%	2.45	09200
CHEERIOS,General Mills	0.448	0.122	0.127	12.73%	1 ounce	104	5.21%	2.44	08013
TROUT,rainbow,farmed,baked/broiled	0.202	0.120	0.172	17.20%	3 oz.	143	7.15%	2.41	15241
WATERMELON	0.036	0.119	0.054	5.44%	1 cup	46	2.28%	2.39	09326
CUCUMBER,unpeeled	0.018	0.119	0.009	0.93%	1/2 cup	7.8	0.39%	2.38	11205
LEMON juice	0.026	0.119	0.008	0.81%	1/8 cup	6.8	0.34%	2.38	09152
SALMON,pink,canned	0.166	0.119	0.141	14.10%	3 oz.	118	5.90%	2.39	15084
BLUEBERRY	0.067	0.117	0.099	9.89%	1 cup	84	4.22%	2.35	09050
TUNA,light,canned in water,drained	0.127	0.109	0.108	10.80%	3 oz.	99	4.95%	2.18	15121
GRAPEFRUIT,pink/red	0.045	0.108	0.056	5.57%	1/2 each	52	2.58%	2.16	09112
CANTALOUPE	0.036	0.105	0.056	5.56%	1 cup	53	2.65%	2.10	09181
PEACH	0.039	0.099	0.058	5.80%	Medium	59	2.93%	1.98	09236
SALMON,Atlantic,farmed,baked/broiled	0.196	0.095	0.167	16.70%	3 oz.	176	8.80%	1.90	15237
SWEET potato,peeled,boiled	0.068	0.089	0.078	7.75%	1/2 cup	87	4.33%	1.79	11510
CORN FLAKES,Kellogg	0.323	0.089	0.092	9.16%	1 ounce	103	5.13%	1.79	08020
LIME juice	0.022	0.088	0.007	0.68%	1/8 cup	7.7	0.39%	1.77	09160
APRICOT	0.042	0.088	0.066	6.58%	1 cup	74	3.72%	1.77	09021
SHRIMP,boiled/steamed	0.104	0.088	0.089	8.90%	3 oz.	101	5.05%	1.76	15151
RYE flour,dark (whole)	0.285	0.088	0.081	8.10%	1 ounce	92	4.62%	1.76	20063
CHEERIOS,Frosted,General Mills	0.329	0.087	0.094	9.35%	1 ounce	107	5.37%	1.74	08267
HERRING-Sardine,Atlantic,baked/broiled	0.177	0.087	0.151	15.10%	3 oz.	173	8.65%	1.75	15040
RICE KRISPIES,Kellogg	0.333	0.086	0.095	9.47%	1 ounce	110	5.50%	1.72	08065
TANGERINE	0.045	0.085	0.040	3.96%	Medium	47	2.33%	1.70	09218
CHERRY	0.053	0.085	0.074	7.36%	1 cup	87	4.35%	1.69	09070
MILK,soy,fortified	0.036	0.084	0.088	8.78%	1 cup	104	5.22%	1.68	16139
MILK,nonfat	0.028	0.083	0.069	6.91%	1 cup	83	4.17%	1.66	01085
APPLE	0.043	0.083	0.055	5.50%	Medium	67	3.33%	1.65	09003
TUNA,light,canned in oil,drained	0.163	0.082	0.139	13.90%	3 oz.	169	8.45%	1.64	15119
EGGPLANT,boiled	0.028	0.081	0.014	1.42%	1/2 cup	18	0.88%	1.62	11210
NECTARINE	0.035	0.080	0.050	4.98%	1 medium	62	3.12%	1.60	09191
GARLIC,raw	0.118	0.079	0.004	0.35%	1 clove	4.5	0.22%	1.58	11215
EGG,raw	0.111	0.078	0.056	5.57%	1 large	72	3.58%	1.56	01123
MANGO	0.047	0.078	0.077	7.68%	1 cup	99	4.95%	1.55	09176
CORN,yellow,boiled	0.074	0.077	0.056	5.57%	1/2 cup	72	3.60%	1.55	11168
FROOT LOOPS,Kellogg	0.288	0.077	0.082	8.18%	1 ounce	106	5.30%	1.55	08030
ORANGE juice,fresh	0.033	0.073	0.081	8.13%	1 cup	112	5.60%	1.45	09206
Applesauce,cnd+vit.C	0.030	0.072	0.074	7.42%	1 cup	103	5.17%	1.44	09401
TILAPIA,baked/broiled	0.091	0.071	0.078	7.80%	3 oz.	109	5.45%	1.43	15262
PEAR	0.041	0.071	0.073	7.32%	Medium	103	5.16%	1.42	09252
EGG YOLK,raw	0.227	0.070	0.039	3.86%	1 yolk	55	2.74%	1.41	01125
AVOCADO	0.111	0.069	0.083	8.34%	1/2 cup	120	6.00%	1.39	09037
ONION,boiled	0.030	0.067	0.031	3.12%	1/2 cup	46	2.31%	1.35	11283
PINEAPPLE	0.033	0.067	0.055	5.52%	1 cup	83	4.13%	1.34	09266
MILK, 1% fat	0.028	0.067	0.068	6.82%	1 cup	102	5.12%	1.33	01082
ORANGE juice,Frz.conc+water	0.030	0.066	0.074	7.38%	1 cup	112	5.60%	1.32	09215
CORN POPS,Kellogg	0.254	0.065	0.072	7.22%	1 ounce	110	5.52%	1.31	08068
CHICKEN,breast,Broil (no bone, skin)	0.108	0.065	0.092	9.20%	3 oz.	141	7.05%	1.30	05064
HAM,regular(9%fat),roasted	0.111	0.063	0.095	9.50%	3 oz.	152	7.60%	1.25	10136
BARLEY,whole,raw	0.221	0.062	0.063	6.27%	1 ounce	101	5.03%	1.25	20004
EGG WHITE,raw	0.032	0.062	0.011	1.07%	1 white	17	0.86%	1.25	01124
PRUNE,dried	0.149	0.062	0.259	25.94%	1 cup	418	20.88%	1.24	09291
HONEYDEW	0.022	0.061	0.037	3.71%	1 cup	61	3.06%	1.21	09184
Applesauce,canned	0.025	0.060	0.062	6.19%	1 cup	103	5.17%	1.20	09019
FROSTED Mini-Wheats	0.213	0.060	0.060	6.05%	1 ounce	101	5.06%	1.20	08459
TRITICALE,flour,whole	0.196	0.058	0.056	5.58%	1 ounce	96	4.80%	1.16	20070
BUCKWHEAT,flour,whole	0.191	0.057	0.054	5.43%	1 ounce	95	4.76%	1.14	20011
YOGURT,plain,nonfat	0.032	0.057	0.078	7.81%	1 cup	137	6.86%	1.14	01118
KAMUT,raw	0.190	0.056	0.054	5.40%	1 ounce	96	4.79%	1.13	20138
CRANBERRY juice,unsweetened	0.026	0.056	0.066	6.55%	1 cup	116	5.82%	1.13	43382
FLOUR,whole wheat	0.191	0.056	0.054	5.42%	1 ounce	97	4.83%	1.12	20080
MILK, 2% fat	0.028	0.056	0.068	6.84%	1 cup	122	6.10%	1.12	01079
CATFISH,farmed,baked/broiled	0.080	0.056	0.068	6.80%	3 oz.	123	6.15%	1.11	15235
BREAD,whole wheat	0.138	0.056	0.037	3.72%	1 slice	67	3.33%	1.12	18075
BEEF,rib eye,lean,broiled	0.111	0.054	0.095	9.50%	3 oz.	175	8.75%	1.09	13098
CHEESE,cottage, 1% fat	0.038	0.053	0.043	4.35%	1/2 cup	81	4.07%	1.07	01016
BREAD,7-grain (whole)	0.141	0.053	0.037	3.66%	1 slice	69	3.45%	1.06	18035
QUINOA,grain	0.194	0.053	0.055	5.50%	1 ounce	105	5.23%	1.05	20035
Chicken noodle soup	0.031	0.052	0.077	7.71%	1 cup	149	7.44%	1.04	06419
GRAPE juice,bottled+vit.C	0.031	0.051	0.078	7.82%	1 cup	152	7.59%	1.03	09130
GRAPE juice,Concord+vit. C	0.031	0.051	0.078	7.82%	1 cup	152	7.59%	1.03	N0235
POTATO,boiled in skin,peeled	0.044	0.051	0.034	3.45%	1/2 cup	68	3.39%	1.02	11831
BARLEY,pearled,flour	0.179	0.051	0.051	5.07%	1 ounce	100	5.00%	1.02	20005
SHREDDED WHEAT	0.170	0.050	0.048	4.82%	1 ounce	96	4.79%	1.01	08147
GRAPE, red and green	0.035	0.050	0.052	5.23%	1 cup	104	5.21%	1.00	09132
MILK,buttermilk,cultured	0.020	0.049	0.048	4.82%	1 cup	98	4.90%	0.98	01088
Fruit coctail in juice	0.028	0.049	0.069	6.95%	1 cup	141	7.07%	0.98	09097
AMARANTH,grain	0.181	0.049	0.051	5.14%	1 ounce	105	5.27%	0.98	20001
MILK,whole	0.030	0.049	0.073	7.26%	1 cup	149	7.44%	0.98	01077
OIL,soybean	0.431	0.049	0.059	5.86%	1 Tbsp.	120	6.01%	0.98	04044
PORK,loin,lean+fat,roasted	0.119	0.048	0.101	10.10%	3 oz.	211	10.55%	0.96	10023
WILD RICE,raw	0.171	0.048	0.048	4.84%	1 ounce	101	5.07%	0.96	20088
Lasagne, meat + sauce	0.068	0.047	0.077	7.68%	4 oz.	163	8.14%	0.94	22916
BEEF,ground,cooked,15% fat	0.109	0.047	0.092	9.20%	3 oz.	198	9.90%	0.93	23569

PORK,spareribs,lean+fat,roasted	0.113	0.047	0.096	9.60%	3 oz.	203	10.15%	0.95	10188
BANANA	0.042	0.047	0.049	4.93%	Medium	105	5.25%	0.94	09040
CORN meal,whole	0.170	0.047	0.048	4.82%	1 ounce	103	5.14%	0.94	20020
OATMEAL,dry	0.171	0.045	0.049	4.87%	1 ounce	108	5.38%	0.90	08120
CHOCOLATE CHIPS, semisweet	0.214	0.045	0.061	6.09%	1 oz.	136	6.82%	0.89	19080
BREAD,rye	0.111	0.043	0.022	2.22%	1 slice	52	2.58%	0.86	18060
CHICKEN,whole,roasted	0.103	0.043	0.087	8.70%	3 oz.	204	10.20%	0.85	05009
MILLET,dry	0.161	0.042	0.046	4.56%	1 ounce	107	5.37%	0.85	20031
BREAD,wheat,enriched	0.110	0.041	0.027	2.75%	1 slice	67	3.33%	0.83	18064
WHEY,fluid,sweet	0.011	0.041	0.027	2.71%	1 cup	66	3.32%	0.82	01114
CORN meal,degermed,enr.	0.151	0.041	0.043	4.28%	1 ounce	105	5.25%	0.81	20022
GRAPE juice,bottled	0.024	0.040	0.061	6.06%	1 cup	152	7.59%	0.80	09135
CHEESE,mozzarella,part skim	0.101	0.040	0.029	2.86%	1 oz.	72	3.60%	0.79	01028
CHEESE,cottage, 4.5% fat	0.038	0.039	0.044	4.35%	1/2 cup	111	5.54%	0.79	01012
Pizza Hut cheese pizza	0.100	0.039	0.096	9.62%	1 slice	250	12.48%	0.77	Not recor
APPLE juice,canned,+vit.C	0.017	0.038	0.043	4.30%	1 cup	114	5.70%	0.75	09400
Applesauce,cnd+sugar	0.026	0.038	0.063	6.27%	1 cup	167	8.36%	0.75	09020
BREAD,oatmeal	0.099	0.037	0.027	2.69%	1 slice	73	3.63%	0.74	18039
YOGURT,plain,whole	0.022	0.037	0.055	5.49%	1 cup	149	7.47%	0.74	01116
CHEESE,Swiss	0.137	0.036	0.039	3.87%	1 oz.	108	5.39%	0.72	01040
BREAD,white,enriched	0.094	0.035	0.023	2.34%	1 slice	67	3.33%	0.70	18069
MILK,evaporated,canned	0.046	0.034	0.058	5.82%	1/2 cup	169	8.44%	0.69	01153
Pizza Hut super supreme pizza	0.106	0.034	0.134	13.42%	1 slice	392	19.62%	0.68	21276
SORGHUM,grain	0.114	0.034	0.032	3.25%	1 ounce	96	4.81%	0.67	20067
RYE flour,light	0.119	0.033	0.034	3.39%	1 ounce	101	5.07%	0.67	20065
BREAD,French	0.096	0.033	0.024	2.40%	1 slice	72	3.61%	0.67	18029
RICE,brown,long grain,raw	0.119	0.032	0.034	3.37%	1 ounce	105	5.25%	0.64	20036
HIGH-C, canned drink	0.015	0.031	0.038	3.79%	1 cup	122	6.08%	0.62	14323
BACON,cooked	0.167	0.031	0.047	4.70%	1 oz.	154	7.70%	0.61	10124
CHICKEN,breast+wing,breaded,fried,fast foo	0.093	0.031	0.079	7.90%	3 oz.	258	12.90%	0.61	21036
CHICKEN,leg+thigh,fried,fast food	0.090	0.031	0.077	7.70%	3 oz.	248	12.40%	0.62	21035
Fried chicken, fast food	0.152	0.031	0.248	24.83%	Breast,wing	805	40.26%	0.62	Not recor
Fruit coctail in heavy syrup	0.028	0.030	0.072	7.22%	1 cup	238	11.90%	0.61	09100
CHEESE,cheddar	0.120	0.030	0.034	3.41%	1 oz.	114	5.71%	0.60	01009
CHEESE,American	0.110	0.029	0.031	3.12%	1 oz.	106	5.32%	0.59	01042
APPLE juice,Frz,+vit.C,diluted	0.014	0.029	0.034	3.39%	1 cup	117	5.83%	0.58	09411
FLOUR,all purpose,enriched	0.105	0.029	0.030	2.98%	1 ounce	103	5.17%	0.58	20081
RICE cake,brown rice	0.110	0.028	0.030	2.97%	2 cakes	104	5.22%	0.57	19816
Burrito, bean & cheese	0.107	0.028	0.198	19.82%	2 each	703	35.15%	0.56	Not recor
French fries, McDonalds	0.148	0.027	0.168	16.85%	Medium	616	30.78%	0.55	Not recor
Ham & cheese sandwich	0.094	0.027	0.138	13.75%	1 each	514	25.70%	0.54	Not recor
RAISINS,raw	0.079	0.026	0.058	5.77%	1/2 cup	218	10.91%	0.53	09298
FLOUR,cake,enriched	0.091	0.025	0.026	2.60%	1 ounce	103	5.14%	0.50	20084
Beginning of the Red Zone Along the Nutrition Contribution Continuum									
CORNBREAD from mix	0.075	0.024	0.021	2.13%	1 ounce	89	4.46%	0.48	18023
COOKIE, Oreo	0.112	0.024	0.038	3.80%	3 each	159	7.97%	0.48	18166
Chicken pot pie	0.109	0.024	0.237	23.70%	1 pie	1007	50.34%	0.47	Not recor
Big Mac with cheese	0.130	0.023	0.271	27.09%	1 each	1177	58.83%	0.46	Not recor
CREAM,half and half	0.030	0.023	0.009	0.89%	2 Tbsp	39	1.95%	0.46	01049
RICE,white,long grain,enr.,raw	0.083	0.023	0.024	2.37%	1 ounce	104	5.18%	0.46	20044
MARGARINE	0.137	0.022	0.007	0.68%	1 pat	31	1.57%	0.44	04629
Shrimp, breaded, fast food	0.094	0.021	0.154	15.40%	6-8 shrimp	745	37.23%	0.41	Not recor
Croissant + egg, cheese, ham	0.094	0.020	0.143	14.33%	1 each	720	36.02%	0.40	21013
ICE CREAM, vanilla	0.039	0.019	0.026	2.60%	1/2 cup	137	6.83%	0.38	19095
PIE, apple	0.044	0.019	0.056	5.56%	1 piece	296	14.81%	0.38	18301
APPLE juice,canned	0.008	0.018	0.020	2.01%	1 cup	114	5.70%	0.35	09016
CREAM,sour,cultured	0.032	0.016	0.008	0.76%	2 Tbsp	46	2.32%	0.33	01056
APPLE juice,Frz,diluted	0.008	0.016	0.019	1.91%	1 cup	117	5.83%	0.33	09018
DONUT, glazed	0.063	0.016	0.038	3.81%	1 medium	242	12.09%	0.32	18436
COOKIE, animal crackers	0.069	0.015	0.020	1.96%	1 oz.	127	6.33%	0.31	18150
CREAM,whipping,heavy	0.053	0.015	0.016	1.58%	2 Tbsp	104	5.18%	0.31	01053
CAKE, yellow, vanilla icing	0.057	0.015	0.036	3.64%	1 piece	239	11.94%	0.31	18141
SUCANAT	0.056	0.015	0.007	0.71%	1 Tbsp.	48	2.39%	0.30	N0076
CHEESE,cream	0.050	0.015	0.014	1.44%	2 Tbsp	99	4.96%	0.29	01017
Hushpuppy, fast food	0.037	0.014	0.029	2.89%	5 each	200	10.02%	0.29	21129
OIL, olive	0.110	0.012	0.015	1.49%	1 Tbsp.	119	5.97%	0.25	04053
Onion rings, breaded, fast food	0.031	0.011	0.025	2.54%	8-9 rings	229	11.45%	0.22	Not recor
SYRUP, maple	0.027	0.010	0.005	0.53%	1 Tbsp.	52	2.60%	0.20	19353
CARAMELS	0.038	0.010	0.011	1.08%	1 oz.	108	5.42%	0.20	19074
BUTTER	0.061	0.009	0.003	0.31%	1 pat	36	1.79%	0.17	01001
GATORADE, FRUIT-FLAVORED	0.001	0.005	0.007	0.75%	20 fl. oz.	158	7.92%	0.09	14460
HONEY	0.005	0.002	0.001	0.11%	1 Tbsp.	64	3.19%	0.04	19296
COKE, PEPSI	0.001	0.002	0.002	0.22%	12 fl. oz.	136	6.81%	0.03	14400
SPRITE, 7-UP	0.001	0.001	0.002	0.19%	12 fl. oz.	148	7.38%	0.03	14145
SUGAR	0.001	0.000	0.000	0.01%	1 Tbsp.	49	2.44%	0.00	19335

Appendix B. Benbrook, Mesnage 2024 *Foods* Paper

Article

Enhanced Labeling to Promote Consumption of Nutrient Dense Foods and Healthier Diets

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*

Abstract: Background/Objectives: Efforts are underway worldwide to design and deploy food labeling systems that provide consumers with the information needed to shift dietary patterns toward nutrient dense, healthier foods. Despite a compelling need for progress, worrisome public health trends persist that are rooted in the popularity of unhealthy, heavily processed foods. **Methods:** The nutrition and health-related content on the packaging of nine common foods sold in the US and Europe is analyzed and compared. The current scope of nutrient-specific messaging is characterized, including messages highlighting health-related benefits stemming from the mix and levels of mostly macronutrients in food products. **Results:** An average of 6.9 unique nutrition-related messages appear on the packaging of nine US food products, while EU food products contain an average of

5.0. Messaging around the ingredients in food products accounts for the largest share, e.g., "100% whole grain", "Vegan", and "No artificial preservatives". The macronutrients of fat, fiber, cholesterol, salt, sugar, and protein are the focus of most messaging around health benefits. The degree of food processing and essential vitamin, mineral, and phytochemical micronutrients receive little or no attention, despite their importance in positive health outcomes. **Conclusions:** Current nutrition- related labeling fails to inform consumers of the enormous differences in the contribution of food products in meeting nutritional needs. Existing metrics and rating systems do not effectively account for the critical relationship between nutrient density and caloric content. Existing metrics and systems do not reflect the impacts of processing on food nutritional quality in ways that provide consumers meaningful information. New concepts, metrics, and label elements are described that could promote healthier dietary patterns. Clear and mandatory nutrition labeling could begin shifting market share toward healthier options, and this could trigger and guide changes in manufactured food recipes that make brand-name products healthier, benefiting all consumers.

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1. Introduction

Opportunities abound to enhance public health through changes in food quality and dietary choices. Nearly one-half of all Americans have one or more chronic health conditions rooted in food and beverages, including 40% of school-age children [1,2]. Only about 25% of individuals aged 17–24 are regarded as prepared for military basic training [3]. There has been an "alarming decline" in food nutritional quality [4–6]. Some 90% of the estimated USD 4.3 trillion in annual health care costs in the US is triggered or made worse by poor food quality and diet-related disease [1–6]. Serious problems have surfaced with the conceptual foundation and scientific integrity of the US Dietary Guidelines, with a focus on their failure to adequately account for associations between food nutritional quality and chronic disease [7–9]. Healthier food and diets will benefit individuals, families, and communities, yet unwelcome trends persist in most countries.

The gap between current and optimal food quality and dietary-intake patterns is enormous, especially in the United States (US) [10,11], including for children [12]. As a result, the US Food and Drug Administration (FDA) is working on a new front-of-pack labeling scheme with the goal of providing shoppers clearer guidance toward healthier choices [13]. The FDA's "Notice" seeking public comments on the definition of healthy food and the design of new front-of-package nutrition labeling appeared in the Federal Register on 26 January 2023 [14]. It states that: "FDA seeks to improve dietary patterns in the United States to help reduce the burden of nutrition-related chronic diseases and advance health equity as nutrition-related diseases are experienced disproportionally by certain racial and ethnic minority groups and those with lower socioeconomic status".

The FDA's effort to enhance nutrition labeling could help set the stage for "food is medicine", a key action item emerging from a 2022 White House Conference on Hunger, Nutrition, and Health [15]. The US government is also promoting the notion of food is or as medicine via a number of initiatives [16,17].

Existing food labeling systems in the US and the European Union (EU) focus predominantly on a food product's macronutrients: calories, fat, cholesterol, carbohydrates, sugar, fiber, protein, and salt (see Section 3 "Results" and Supplementary Tables S1–S18). In the US, a standardized Nutrition Facts panel appears on the back of food packaging (and sometimes a side panel; see examples in Supplemental Tables S1–S18: Front-of-Pack and Back-of-Pack Nutrition and Health-Related Information, Claims, and Messaging on Nine Food Products in the US and the EU). These panels report mostly macronutrient content per serving of food and convey information on serving size and the number of servings in a package. The amount in grams and percent of the Daily Value (DV) is also reported for selected vitamins, calcium, iron, potassium, and some other micronutrients. Similar macronutrient content information appears on product labels in the EU but is typically expressed per 100 g or 100 mL of beverages, and sometimes also per serving. Regulations have been adopted in the EU governing acceptable ways to convey nutrition information to consumers [18] and an effort is underway to improve and harmonize food labeling within Europe [19].

Food packaging contains other food ingredient, nutrient, and nutrition-related information in both the US and EU that fall into three general categories: (1) information about what ingredients are, or are not in a food product (e.g., whole grain, vegan, no bioengineered content), (2) potential or implied health benefit(s) (e.g., promotes heart health, low cholesterol, reduced sodium, healthy bones), and (3) established linkages between the nutrient content in a product and some specific health outcomes (e.g., qualified health claims in the US [20]). Most nutrient- and nutrition-related information on food labels in the US and EU focuses on macronutrient content and impacts on health outcomes.

Raw food ingredients, additives, and other processing agents are included in manufactured-food recipes and must be included in a product's ingredient list in both the US and EU. Given the current focus in biomedical journals and lay media on the impacts of food processing on metabolic syndrome and other adverse health outcomes, food companies and consumers are increasingly focused on a product's degree of processing [21–23]. The NOVA food processing system is named after the word "novel" in Portuguese, and first appeared in the original NOVA paper by Monteiro et al. [24] describing a new system to place foods into one of four categories:

1. Unprocessed or minimally processed foods;
2. Processed culinary ingredients;
3. Processed foods;
4. Ultra-processed foods.

The NOVA system is now used widely to characterize the degree of processing in food labeling and marketing applications, as well as in epidemiological research exploring associations between the degree of food processing and diverse health outcomes [25]. In Europe, Nutri-Score values are now encouraged in several countries and appear on many food products [26,27]. Like NOVA in the US, Nutri-Score values are also beginning to be used in epidemiological studies (e.g., [28,29]).

Questions persist, however, over whether existing systems provide a sufficiently accurate basis for delineating healthy from unhealthy food choices [30–39]. The EU's food labeling regulations also do not quantify the degree of processing or provide clear guidance to consumers who seek to avoid ultra-processed food [18]. As part of the European Farm to Fork strategy, the European Commission was called upon and expected to propose a harmonized, mandatory front-of-pack nutrition labeling scheme by the end of 2023 but has yet to do so. Responsible authorities in the EU are struggling to work through the same technical, messaging, and political issues and undercurrents that are proving challenging for the US FDA [33,35–38].

Research led by Serge Hercberg from the University of Sorbonne and University Paris Cité developed and tested "Nutri-Score 2.0", an enhanced nutrition label that includes a prominently displayed warning about ultra-processed foods [28]. The study involved over 21,000 participants who assessed products with the standard Nutri-Score, the modified version, or no label. Nutri-Score 2.0 improved consumers' understanding of nutrient content and the degree of processing. Most participants found the Nutri-Score 2.0 label credible and helpful, with 88% supporting its use on packaging.

A review by Devaux et al. [36] compares four front-of-pack labeling systems, including Nutri-Score, Keyole, Nutri-Repere, and Nutri-Couleurs. Compared to the three other systems, Nutri-Score was deemed superior in reducing caloric intake and improving public health. Nutri-Score led to an estimated 3% reduction in calories. While even such modest progress is welcomed, change sufficient to meaningfully alter disturbing food and diet-driven public health trajectories will almost certainly require more effective interventions.

A system designed to support nutrition-health labeling on food packages (front, back, top, bottom, and sides) that targets consumers is inevitably going to differ from a system designed to support epidemiological research exploring the health outcomes stemming from food nutritional quality, degree of processing, and food choices and dietary patterns. Ideally, the core concepts and metrics used to support nutrition labeling and conduct food-health research will share common roots, but operational details will invariably diverge.

To provide consumers with reliable guidance on how to shift dietary patterns in ways likely to enhance health outcomes, it is essential to quantify the nutritional quality of one category of food product compared to others (e.g., breakfast cereal to fresh fruit), as well as between one brand of a particular food compared to competing brands (Cheerios versus Cheerios with Honey or Raisin Bran).

Herein, we argue that such a system should quantify nutritional quality on the basis of a recommended serving of food, as opposed to on the basis of an equal number of grams or ounces of food, or a set number of calories (e.g., 100 calories). A focus on serving sizes will provide nutritional quality guidance to consumers in a way aligned with the information on Nutrition Facts panels that are also expressed per serving. Previously, Benbrook, Mesnage, and co-authors submitted comments to the FDA on its "Proposed rule" for new FOP labeling that identified the serious problems with the FDA's proposed approach and recommended alternative metrics for incorporation in a hypothetical labeling system called NuCal [40].

The FDA is developing front-of-pack nutrition labeling options that convey graphically the most important information on macronutrient content that is currently contained in Nutrition Fact panels. Current options under consideration by the FDA appear in Figure 1.

Among many challenges, both technical and political, the FDA must decide the macronutrient "take home" messages to feature in simple yet hopefully compelling front-of-pack graphics [39,41]. But to date, the FDA has not publicly discussed ways to provide consumers comparable information on many other nutrients essential in achieving positive public health outcomes, nor has the FDA addressed what to communicate, if anything, about the degree and impacts of food processing.

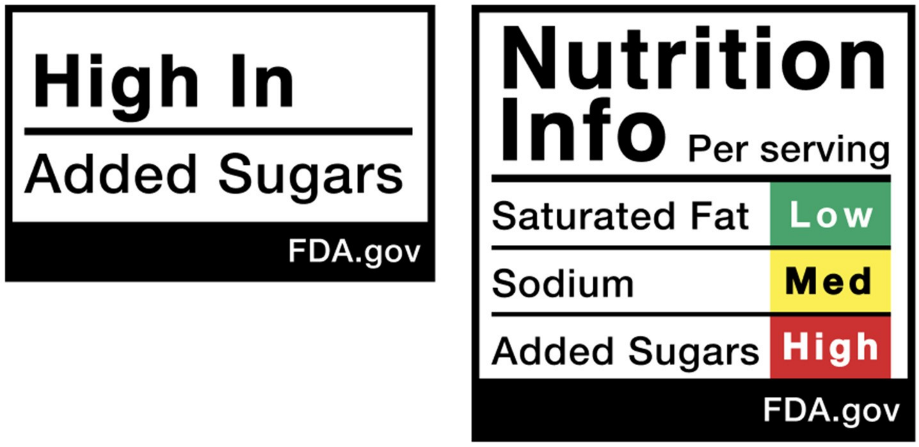


Figure 1. Graphics displaying macronutrient composition under consideration for front-of-pack nutrition labeling by the US FDA.

In this paper, we assess the nutrient- and nutrition-related information on the packaging of a representative sample of foods and brands for sale in the US and EU. We critique current nutrition-related messaging and identify other key nutritional quality attributes of food that are not addressed adequately, or at all. Suggestions are made to improve the content on food packaging based on the FDA's stated purpose in its ongoing review of FOP options. The impacts over time of improved, clearer, and mandatory nutritional labeling on the recipes used by food manufacturers, and hence also on the nature and degree of processing, is emphasized as a secondary benefit of food labeling that shifts purchase decisions toward healthier products.

2. Materials and Methods

Nine common food products sold in the US and EU were selected for the assessment of their label content: Cheerios, oatmeal, Pringles, whole wheat bread, plant-based ground round (i.e., plant-based hamburger), whole milk, almond milk, Thousand Island salad dressing, and ketchup. All the products entail a degree of processing (milk is pasteurized and fortified) and several are or would likely be classified as ultra-processed under the NOVA system (e.g., Pringles, Thousand Island dressing).

We use the nutritional quality metric described herein to calculate values for a selection of foods ranging from heavily processed to whole, fresh food forms. Details of the nutrient profiling system used to generate these values are described below and in Supplemental File: Methodology and Data Sources in Calculating Nutritional Quality Values for Specific Foods.

2.1. Nutrient and Nutrition-Health Messaging on Labels

We captured all nutrient- and nutrition-health-related information on food package labeling, including information on the front-of-pack (FOP), back-of-pack (BOP), and if any, side and top-and-bottom panels. Quantitative indicators are reported of the over- all content of nutrient-specific and nutrition health-related label messages appearing on product packaging.

On some food products, the same or similar nutrition health-related information appears more than once. The number of repeated messages on each product's packaging is reported and taken into account when computing the number of unique nutrient content and nutrition health-related information items. Pictures of the nutrition-related content on food product packaging for each of the nine foods from both the US and EU markets appear in Supplemental File Tables S1–S18, along with the content and number of messages. There are two Supplemental Tables for each food. One compares the front-of-pack content of the food product sold in the US to the same food product sold in Europe. The second

Supplemental Table for each food covers all nutrient- and nutrition-related label content on the back-of-pack, and side and/or bottom-top panels (if any).

Information items on food packaging that has relevance in communicating the nutrient content, nutritional quality, and healthfulness of a given food product are placed in one of three categories (see Table 1):

- Content Information;
- Implied Health Benefit, and;
- Qualified Health Claim.

Table 1. Categories of nutrient and nutrition-health information on food product labels.

	Content	Attributes	Nutrient-Health Outcome
Content Information	"100% Whole Grain", Vegan, No High Fructose Corn Syrup	Low or no processing, No animal products, more "natural" ingredients	Not specified
Implied Health Benefit	"Good Source", "Low In", Nutri-Score value	Linkage of "high" or "low" content claim to some generally recognized positive attribute	Not specified
Qualified Health Claim	Difference in one or more ingredients linked to a specific health outcome	Higher or lower content of an ingredient or nutrient(s) linked to a specific health outcome	Heart healthy; Lowers cholesterol; Improved gut health; Stronger bones

"Content Information" refers to one or more of the ingredients in a food product. Such messaging links an ingredient in the food product to some presumptively positive attribute. For example, messaging related to gluten content, whether the food is vegan, or contains "whole" ingredients, fall in the "Content Information" category, whereas claims regarding recycling, impacts on rainforests, or fair trade and treatment of workers are excluded for lack of relevance to nutritional quality.

Two characteristics apply to messages in the "Implied Health Benefit" category. First, such messages refer to a relatively higher or lower level of one or more specific nutrients or ingredients in a food product, compared to competing brands and/or other foods. Second, the higher or lower level of certain ingredients and/or nutrients in the product is generally thought to promote a positive health outcome in light of government-set, recommended daily intakes. Nutri-Score [26,42] or NOVA [23,24] system ratings would fall in this category since the scores in both systems are based on various nutrient-related attributes or shortcomings in a food product that can impact health outcomes. Messages in this category do not communicate a generally accepted association between a health benefit and the contents of the food product.

The third category includes label information and messaging that communicates a specific linkage between an altered level of one or more nutrients in a food product and some specific and named health outcome (e.g., CVD, osteoporosis). In the US, the FDA has established a rigorous, data-rich process for approving or denying petitions that propose a new "Qualified Health Claim" on food packages, as well as in advertising and other channels of communication [20]. Petitions may be submitted to the FDA by food companies or other entities (e.g., a commodity group representing tomato growers, a research institute).

Such health claims are "qualified" by specifying the circumstances in which an association between some identified attribute in a food product (e.g., 30% more calcium) is expected to promote a positive health outcome (stronger bones) or lower the risk of a negative one (osteoporosis). Qualifying statements often include the circumstances in which the outcome is likely to occur (e.g., "in conjunction with a healthy lifestyle" or "when part of a healthy diet").

For each of the nine food products, we counted the total number of nutrient and health-related messages on product packaging within each of the three categories in Table 1. The average number of messages by category is reported in Table 2 below.

Table 2. Significant differences exist in nutrition-related labelling on selected foods in the US and EU.

Food	Brand	Number Front-of-Pack --				Number Back-of-Pack or Other --				Number Repeated	Total Number Unique
		Content Information	Implied Health Benefit	Health Claim	Total	Content Information	Implied Health Benefit	Health Claim	Total		
U.S. Food Brands											
Cheerios	General Mills	2	7	2	11	1	0	2	3	3	11
Oat cereal	Quaker Oats	1	0	1	2	2	0	1	3		5
Pringles	Pringles LLC	2	0	0	2	0	0	0	0	0	2
Whole Wheat Bread	Nature's Own	9	1	1	11	7	2	2	11	8	14
Plant-based ham-burger	Nature's Promise	6	1	0	7	1	0	0	1	0	8
Whole Milk	Oakhurst	1	1	0	2	2	1	0	3	1	4
Almond Milk	Blue Dia-mond	4	1	0	5	10	2	0	12	4	13
1000 Island	Kraft	2	0	0	2	2	0	0	2	1	3
Ketchup	Heinz	0	0	0	0	2	0	0	2	0	2
Average US Products		3.0	1.2	0.4	4.7	3.0	0.6	0.6	4.1	1.9	6.9
E.U. Food Brands											
Cheerios	Nestle	8	0	0	8	4	1	0	5	0	13
Oat cereal	Edeka	2	1	0	3	1	1	0	2	1	4
Pringles	Kellogg	1	1	0	2	0	1	0	1	0	3
Whole Wheat Bread	Golden Toast	4	0	2	6	1	0	0	1	1	7
Plant-based ham-burger	Edeka	1	2	0	3	2	0	0	2	1	4
Whole Milk	Milsani	1	2	0	3	5	1	0	6	2	7
Almond Milk	Alpro	1	1	0	2	2	1	0	3	1	4
1000 Island	Kuhne	1	1	0	2	1	1	0	2	1	3
Ketchup	Heinz	0	0	0	0	1	0	0	1	0	1
Average EU Products		2.1	0.9	0.2	3.2	1.9	0.7	0.0	2.6	0.8	5.0

Notes: 1. Nutrient and nutrition-related information on the packaging of EU products has been obtained from the database openfoodfacts (https://world.openfoodfacts.org, accessed on 1 September 2024), and actual packaging on some products sold in Germany. Some of the information and claims on certain products change overtime, and varies from country-to-country in the EU. Thus, our analysis the number of nutrition-related information items on EU food packaging is an approximate snapshot of the nine products in the EU.

2.2. Quantifying and Ranking the Nutritional Quality of Food Products

Our preferred framing of "nutritional quality" in the context of a food labeling system intended to improve public health outcomes is the degree to which a serving of food meets essential nutrient needs, while not taking up a disproportionate share of daily caloric space (e.g., 2000 calories per FDA guidance). Such a metric takes account of the portion of essential nutrients in a serving of food relative to applicable Recommended Daily Intakes for each nutrient, and the share of daily caloric intake fulfilled by that serving of food. Such a metric is part of a hypothetical food labeling system called NuCal that is described in the HHRA comments to the FDA [40]).

A nutrient profiling system is required to quantify the NuCal metric for a given serving of food [40,43]. There are 27 nutrients in the NuCal system: eleven vitamins, eight minerals, protein, fiber, antioxidant activity as measured by total ORAC, lutein + zeaxanthin, linoleic acid, linolenic acid, lycopene, and choline. RDA-equivalent daily intake levels regarded as necessary to avoid health problems and serving sizes are from US government documents, or in the absence of a government-set value, recommended intakes advanced by public or private sector authorities with recognized expertise in the nutritional sciences.

The basic, single-nutrient metric in one serving of food is a ratio: nutrient (mg)/RDA (mg) (or equivalent). This is expressed as a percentage.

The NuCal value for one serving of fresh orange is calculated as follows:

$$\text{NuCal Value} = \text{NQI}/\%\ \text{Caloric Space}$$

where

NQI is the Nutritional Quality Index, i.e., the % of daily needs across 27 nutrients that is satisfied by the nutrients in one medium-sized orange (NQI = 7.54%);
% Caloric Space is the share of a 2000 calorie diet taken up by the calories in one medium-sized orange (62 calories; 62/2000, or 3.1%)

We have calculated the NuCal values for 196 common foods (see Supplemental File: NuCal and Nutritional Quality Index (NQI) Values for 196 Foods in Three Zones Along the Nutritional Quality Continuum). The foods include dozens of single-ingredient fresh and whole foods; cereals; grain-based products; meat, poultry, and fish; and several multi-ingredient foods (pepperoni pizza, a Big Mac and fries). Values for some foods are reported based on different food forms (fresh grapes versus raisins or grape juice) and methods of cooking (fresh, fried, boiled). For the 196 foods, NQI values are calculated per 100 g of food, per 100 calories, and per typical serving size. The later NQI value based on the grams or ounces in a serving of food is used in the NuCal system.

A medium orange delivers 7.5% of the total nutrients needed to sustain health based on RDAs or equivalent intake benchmarks, and the weights assigned to nutrients in the NQI (see details on weighting in Supplemental File: Methodology and Data Sources in Calculating Nutritional Quality Values for Specific Foods). The NuCal value for a medium orange pr serving is 2.4 (7.5%/3.1%). Accordingly, a medium-sized orange delivers 2.4 times more progress toward satisfying daily nutrient needs than the caloric space taken up by the calories in a medium-sized orange.

Several decisions and assumptions have to be made in order to calculate NuCal values for any given food. The way each of these issues is addressed in calculating NuCal values for specific foods assessed in this paper is noted in in each of the six items addressed below. Regardless of the metrics chosen as the basis of future nutritional quality labeling systems, a method to deal with the following six computational issues will need to be developed and vetted:

1. What essential nutrients should be included (e.g., the 27 in NuCal, or some other set).
2. How to set a widely applicable, recommended daily intake level for each nutrient deemed essential (e.g., in NuCal, RDAs, other benchmark intakes sufficient to sustain good health for adult women, or some other population cohort).

3. Weights assigned to individual nutrients in the calculation of overall nutritional quality; e.g., a higher weight on a nutrient that is routinely consumed at inadequate levels, or vice versa. The NuCal system assigns initial weights to each of the 27 nutrients, and then adjusts these initial weights by the degree to which the nutrient is over or under-consumed relative to recommended intake levels (details in Supplemental File: Methodology and Data Sources in Calculating Nutritional Quality Values for Specific Foods).
4. What to do when a serving of food contains more than 100% of the RDA or comparable intake benchmark for a given nutrient (e.g., cap the maximum score for any one nutrient at 1 or some higher number). NuCal caps the contribution of an individual nutrient at 5 times the applicable RDA or equivalent, a limit that rarely applies when NQI/NuCal values are calculated per serving.
5. Whether and how to include nutritional supplements. NuCal values include additional nutrients in "fortified" food products; values based on just the nutrients in the raw food ingredient can be calculated and are discussed below.
6. How to address fatty acid profiles in animal products and vegetable oils to encourage the shift from heart-unhealthy fats to heart-healthy or neutral ones. NuCal partially addresses fatty acid profiles by including linoleic acid.

Answers to these questions will allow the research community, stakeholders, and the FDA to identify the additional food product testing needed and calculations that will produce a nutritional quality score for a serving of a given food product. The higher the number, the more valuable the food is in meeting a person's daily nutritional needs. The values can be used to create a continuum with zones ranging from super-foods to those foods delivering little or no nutritional value. A prospective food nutritional quality continuum based on the NuCal metric could be broken into three zones:

- Green Zone—healthiest options (also known as super-foods): NuCal values above 4.
- Yellow Zone—moderately healthy options: NuCal values between 0.5 and 4.
- Red Zone—less healthy options: NuCal values less than 0.5 (also known as junk food, especially when NuCal values fall below 0.1).

Future labeling systems could then highlight where a serving of a given food lies along such a continuum (an example follows). A food product-specific value could also be compared to the average value among competing brands of the same or similar products, or all products in a food group.

2.3. Degree of Processing

There are two characteristics of food products that impact nutritional quality and consumer perceptions of healthfulness. One is the degree to which food recipes and manufacturing processes have altered the nutrients in the final product, compared to the nutrients in the raw food ingredients used to make the product. In the NuCal system, there are three food processing metrics. Two are calculated across a set of nutritionally significant nutrients, such as the 27 in NuCal.

For each nutrient deemed nutritionally significant, the total milligrams of the nutrient in one serving of a food product as sold must be calculated. Then, the quantity of each nutrient in the serving of food from supplements, if any, should be subtracted from the total of that nutrient in the food product. The first metric is the percent share of each nutrient that comes from the raw ingredients in a serving of food (total amount of each nutrient minus amount from supplements, expressed as a percent of total nutrient levels). A second metric reflects the impact of processing, supplements, and fortification on the levels of nutrients in a food product as sold: the percent of each nutrient in the raw ingredients required to manufacture a serving that remain in the final product as sold. These first two metrics can be calculated for each nutrient in the evaluation system and added together in various ways to give a global estimate of the impact of processing and fortification on food nutritional quality.

The second processing and manufacturing characteristic of concern to consumers and the public health community is the number and quantities of ingredients added to the recipe to augment the primary raw food ingredients in some way (preservation, stability, cooking properties, color, mouth feel). A third metric would reflect the number of additives and supplements in the product and the percent of total weight accounted for by such additives.

Gathering these data should be simple. The number of additives can be derived from the ingredient lists that already appear as part of Nutrition Fact panels in the US, as well as somewhere on food packaging in the EU. Food manufacturers would also need to supply the concentrations of each additive in a product's recipe.

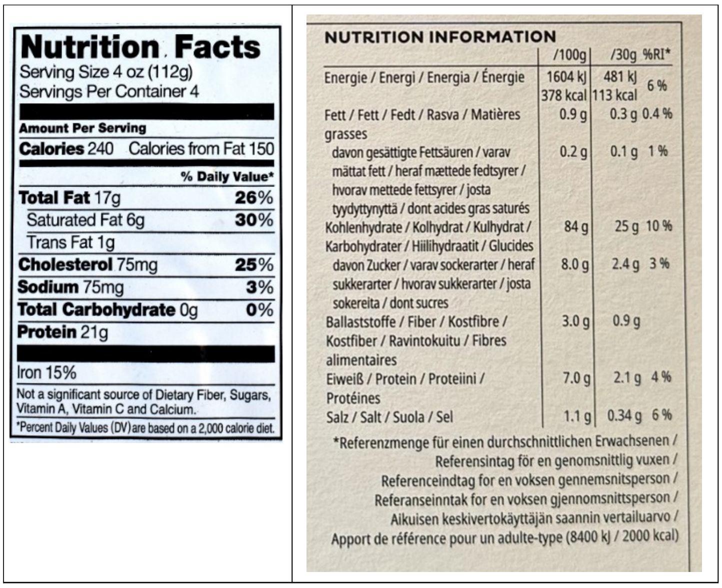
These three simple metrics would provide various ways to quantify the degree to which food processing alters the nutritional content in manufactured food products, and could include the number of such ingredients in a finished food product, the number of ingredients in a manufactured product compared to the ingredients a consumer would typically use at home when making the same or similar food, and/or the combined weight of non-food, added ingredients expressed as a percentage of the grams of raw food ingredients a single serving of the food product.

3. Results

Information on the macronutrients in food products is reported in Nutrition Fact panels in the US and similar "Nutrition Information" boxes that appear on EU food products. Data are presented on fat content including total fat and type of fat (saturated, monounsaturated, polyunsaturated, trans fat); cholesterol; sodium; total carbohydrates; fiber; natural sugars and added sugar; and protein. Additional boxes of variable length across food products present the micrograms or milligrams and/or the percent of Daily Value for a generally small number of vitamins, minerals, and other micronutrients in the food product.

Nutrition Facts panels specify serving sizes, as well as the total number of servings in the package. Serving sizes are typically reported in terms of cups, number of pieces, or in grams or ounces (see Figure 1).

Similar but generally less extensive information is presented on the nutrients in food products sold in the EU (see the labels in Supplemental Tables S1–S18: Front-of-Pack and Back-of-Pack Nutrition and Health-Related Information, Claims, and Messaging on Nine Food Products in the US and the EU). Unlike in the US where all nutrient data are reported per serving, "Nutrition Information" boxes in the EU report nutrient levels per 100 g, and sometimes other quantities such as 30 g or per serving, as shown in Figure 2.



Nutrition Facts

Serving Size 4 oz (112g)
Servings Per Container 4

Amount Per Serving	
Calories 240	Calories from Fat 150
	% Daily Value*
Total Fat 17g	**26**%
Saturated Fat 6g	**30**%
Trans Fat 1g	
Cholesterol 75mg	**25**%
Sodium 75mg	**3**%
Total Carbohydrate 0g	**0**%
Protein 21g	
Iron 15%	

Not a significant source of Dietary Fiber, Sugars, Vitamin A, Vitamin C and Calcium.

*Percent Daily Values (DV) are based on a 2,000 calorie diet.

NUTRITION INFORMATION

	/100g	/30g	%RI*
Energie / Energi / Energia / Énergie	1604 kJ 378 kcal	481 kJ 113 kcal	6 %
Fett / Fett / Fedt / Rasva / Matières grasses	0.9 g	0.3 g	0.4 %
davon gesättigte Fettsäuren / varav mättat fett / heraf mættede fedtsyrer / hvorav mettede fettsyrer / josta tyydyttynyttä / dont acides gras saturés	0.2 g	0.1 g	1 %
Kohlenhydrate / Kolhydrat / Kulhydrat / Karbohydrater / Hiilihydraatit / Glucides	84 g	25 g	10 %
davon Zucker / varav sockerarter / heraf sukkerarter / hvorav sukkerarter / josta sokereita / dont sucres	8.0 g	2.4 g	3 %
Ballaststoffe / Fiber / Kostfibre / Kostfiber / Ravintokuitu / Fibres alimentaires	3.0 g	0.9 g	
Eiweiß / Protein / Proteiini / Protéines	7.0 g	2.1 g	4 %
Salz / Salt / Suola / Sel	1.1 g	0.34 g	6 %

*Referenzmenge für einen durchschnittlichen Erwachsenen / Referensintag för en genomsnittlig vuxen / Referenceindtag for en voksen gennemsnitsperson / Referanseinntak for en voksen gjennomsnittsperson / Aikuisen keskivertokäyttäjän saannin vertailuarvo / Apport de référence pour un adulte-type (8400 kJ / 2000 kcal)

Figure 2. Boxes Providing Information on Macronutrient Composition on Products Sold in the US and EU.

3.1. Macronutrient Labeling on Nine Foods Sold in the US and in Europe

The number of nutrient-specific and nutrition health messages on the packaging of the nine food products sold in the US and EU appear in Table 2 and are derived from the 18 Supplemental Tables (two tables per product type in Supplemental Tables S1–S18: Front-of-Pack and Back-of-Pack Nutrition and Health-Related Information, Claims, and Messaging on Nine Food Products in the US and the EU: (1) front-of-pack and (2) back-of-pack, sides, and top/bottom). For the US products, there was a total of 42 messages on front-of-pack labeling, or an average of 4.7 messages per food. On average, there were 3.0 front-of-pack messages containing Content Information, 1.2 messages with Implied Health Benefits, and 0.4 Qualified Health Claims. In back-of-pack and side panel labeling/packaging, there was an average total of 4.1 messages, with Content Information messages accounting for 3.0, or 73%. There were, on average, 1.9 repeat messages on food product packaging, resulting in an average of 6.9 unique messages across the nine US food products.

Among the US products, whole wheat bread and almond milk packaging contained the highest number of unique messages (14, 13). Whole wheat bread contained a total of 22 messages, 8 of which appeared twice for a total of 14 unique messages. There were 11 unique messages on the Cheerios packaging that were heavily weighted toward health benefits. Out of a total of 14 messages on Cheerios packaging, 7 noted Implied Health Benefits and 4 were Qualified Health Claims (including 2 repeated Qualified Health Claims). The packaging of the plant-based ground round (hamburger) contained 8 unique messages, 7 of which entailed Content Information on the FOP. The other five foods contained two to five unique messages, and only one Qualified Health Claim (oatmeal, fiber, and overall health).

The total number and number of unique messages on EU packaging across the nine foods were lower than in the US. In terms of Content Information, there were 19 messages on EU product FOP labeling versus 27 on US FOP labeling. There were 8 FOP Implied Health Benefit messages on EU product packaging, compared to 11 in the US. There were two Qualified Health Claims on the FOP across the nine EU products and four in the case of the US. The same or similar health benefits were associated with nutrient content-related claims on US and EU food packaging.

The biggest difference in the messaging on the US foods in contrast to the EU counterparts occurred in the case of the two plant-based alternatives to animal-based foods: the plant-based ground round and almond milk. Across the two plant-based food alternatives for sale in the US, there were a total of 21 unique messages. There was a total of eight unique messages on the packaging of the comparable EU products, which was only 38% of the US total.

3.2. Nutritional Quality Score for Common Foods

The NuCal system nutritional quality scores for specific foods presented below are preliminary and based on a specific set of assumptions, adjustments, and calculations [40]. The US FDA, government agencies in any other country, food companies, or different teams of scientists would surely make different judgements about what nutrients belong in such a calculation, how to quantify nutrient density and compare it to nutrient needs and caloric intake, and whether and how to make adjustments to values based on other considerations (e.g., inadequate versus excess intakes of a given nutrient, the seriousness and/or reversibility of an adverse health outcome brought about by inadequate or imbalanced nutrient intakes).

Table 3 reports NuCal values for 33 widely consumed foods from several food groups, including some multi-ingredient foods. These 33 foods were selected from the Supplemental Table containing 196 foods (see Supplemental File: NuCal and Nutritional Quality Index (NQI) Values for 196 Foods in Three Zones Along the Nutritional Quality Continuum). In Table 3, raw spinach has the highest NuCal value (17.1). A single serving of raw spinach would provide 5.9% of the total nutrient needs, while taking up only 0.35% of an individual's 2000 calorie daily diet. Oreo cookies had the highest NuCal value in the third, least-healthy red zone (0.48), and is an example of a food that takes up about twice the caloric space relative to the percent of nutrient needs satisfied.

Table 3. NuCal system values per serving for selected foods in three zones along the nutritional quality continuum.

	% Nutrient Needs Met	Serving Size	Calories	% Daily Caloric Need	NuCal Value
Green Zone (NuCal Value 4 or Greater)					
SPINACH, raw	5.88%	1 cup	6.9	0.35%	17.05
LETTUCE, Romaine	6.12%	1 cup	8.0	0.40%	15.32
BROCCOLI, boiled	12.05%	1/2 cup	27	1.37%	8.83
LIVER, calf, braised	56.20%	3 oz.	164	8.20%	6.85
ALL-BRAN, Kellogg	21.78%	1 ounce	74	3.69%	5.90
CARROT, boiled	7.01%	1/2 cup	27	1.37%	5.13
TOMATO, red	4.05%	1/2 cup	16	0.81%	5.00
STRAWBERRY	10.58%	1 cup	49	2.43%	4.35
GREEN BEANS, boiled	4.66%	1/2 cup	22	1.10%	4.22
Beginning of the Yellow Zone (NuCal Value Between 0.5 and 4)					
ORANGE	7.54%	Medium	62	3.08%	2.45
CHEERIOS, General Mills	12.73%	1 ounce	104	5.21%	2.44
BLUEBERRY	9.89%	1 cup	84	4.22%	2.35
APPLE	5.50%	Medium	67	3.33%	1.65
BREAD, whole wheat	3.72%	1 slice	67	3.33%	1.12
POTATO, boiled, peeled	3.45%	1/2 cup	68	3.39%	1.02
MILK, whole	7.26%	1 cup	149	7.44%	0.98
BANANA	4.93%	Medium	105	5.25%	0.94
OATMEAL, dry	4.87%	1 ounce	108	5.38%	0.90
Pizza Hut cheese pizza	9.62%	1 slice	250	12.48%	0.77
YOGURT, plain, whole	5.49%	1 cup	149	7.47%	0.74
RICE, brown, long grain	3.37%	1 ounce	105	5.25%	0.64
BACON, cooked	4.70%	1 oz.	154	7.70%	0.61
CHEESE, cheddar	3.41%	1 oz.	114	5.71%	0.60
French fries, McDonalds	16.85%	Medium	616	30.78%	0.55
Beginning of the Red Zone (NuCal Value less than 0.5)					
COOKIE, Oreo	3.80%	3 each	159	7.97%	0.48
Chicken pot pie	23.70%	1 pie	1007	50.34%	0.47
Big Mac with cheese	27.09%	1 each	1177	58.83%	0.46
COOKIE, animal crackers	1.96%	1 oz.	127	6.33%	0.31
SYRUP, maple	0.53%	1 Tbsp.	52	2.60%	0.20
BUTTER	0.31%	1 pat	36	1.79%	0.17
GATORADE	0.75%	20 fl. oz.	158	7.92%	0.09
COKE, PEPSI	0.22%	12 fl. oz.	136	6.81%	0.03
SUGAR	0.01%	1 Tbsp.	49	2.44%	0.00

Braised calf liver is by far the most nutritious food per serving in Table 3. A 3 ounce serving provides over 56% of the essential nutrients needed per day in the NuCal system, while accounting for only 8.2% of a 2000 calorie diet (56%/8.2% = 6.8 NuCal value). A medium-sized serving of McDonald's french fries, however, take up 31% of a person's caloric allotment, while delivering 16.9% of nutrient needs, for a NuCal value of 0.56. A Big Mac with cheese lands in the red zone with a NuCal value under 0.5 (0.46). A Big Mac with cheese plus a serving of fries would take up 89% of a person's daily allotment of calories, while delivering almost 44% of the 27 essential nutrients.

Based on caloric data available a few years ago, a Big Mac with cheese, medium fries, and a 12-fluid ounce Coke or Pepsi (i.e., a typical Value Meal) would account for 1929 calories, or all but 71 of a person's daily 2000 calorie allotment. Such a "Value" Meal also satisfies 44% of daily nutrient needs. But it is not possible to consume the other 56% of daily nutrient needs from foods accounting for only 71 calories. This is why excessive caloric intake from common fast food meals, and not just from McDonalds, is a massive hurdle standing in the way of meaningful progress in improving diet-health outcomes.

The differences in NuCal scores across the three zones of the food nutritional quality continuum are summarized in Table 4. The average food in the healthiest green zone has a NuCal value of 8.1. The 15 foods in the middle, or yellow zone, have an average NuCal value of 1.2, while the average of the 9 foods in the least-health red zone has a NuCal value of 0.2.

Table 4. Average NuCal values per food by zone along the nutritional quality continuum: 33 selected foods.

	Number of Foods	**Sum NuCal Values in Zone**	**Average NuCal Value per Food**
Green Zone	9	72.7	8.1
Yellow Zone	15	17.8	1.2
Red Zone	9	2.21	0.25
Totals Three Zones	33	92.6	2.8
Difference Between			
Green and Yellow Zones			6.8
Yellow and Red Zones			4.8
Green and Red Zones			32.9
Percent of Total NuCal Values in Three Zones			
Green Zone		78.4%	
Yellow Zone		19.2%	
Red Zone		2.4%	

Based on the average NuCal values in each zone, food in the green zone delivers almost 33 times more nutrition quality value than the average food in the red zone. Note also that the 9 foods in the green zone have a total NuCal value expressed as a percent of all 33 foods that is about four times higher than the 15 foods in the yellow zone (78.4% versus 19.2%). The 9 foods in the red zone account for just over 2% of the total NuCal values across the 33 foods. This is why efforts to motivate consumers to replace a red zone food choice with a green zone food could make such a substantial contribution to an individual's health, as well the as attainment of national public health goals.

4. Discussion

Most heavily processed, multiple ingredient foods account for a large and growing share of daily caloric intake in many countries and include widely consumed fast foods and beverages that deliver no or very few essential nutrients [43,44], as made clear in Table 4. The food labeling challenge is also enormous. Some 60% of 651 food products marketed for infants and toddlers in the US failed to meet recommended nutrient levels and nearly all products contained one or more prohibited food-health claim, and remarkably, some made up to eleven prohibited claims [12].

Serious deficiencies in micronutrient intakes are surprisingly common in the US and the global food supply. Passarelli et al. report that 4 to 5 billion people on the planet do not consume adequate levels of multiple micronutrients including iodine, Vitamin E, calcium, iron, riboflavin, folate, and Vitamin C, and that women experience greater deficiencies than men [10]. The "What We Eat in America" database reports inadequate intakes for multiple micronutrients across different segments of the US population, with some segments consuming 50% or less than recommended daily intakes [44]. The ratio of omega-6 to omega-3 intakes for the average American exceeds 15:1, and far exceeds the 4:1 or lower ratio that is regarded as heart-health neutral or positive [45–47].

For each individual day-to-day, the basic nutrition-related challenge entailed in promoting healthier food choices is conceptually simple: Everyone should consume adequate levels of some two-dozen essential nutrients via food and beverages, and do so while avoiding prolonged, excessive caloric intake.

This is why nutritional quality metrics used to communicate differences across foods via simple front-of-pack label content should ideally be based on overall nutrient content and density relative to caloric space. This will likely prove to be the best option for any front-of-pack nutritional quality labeling scheme that has, as its North Star, the improvement in public health outcomes.

For the foreseeable future, food product labels in the US, EU, and much of the world are likely to contain the following:

- The basic information now presented in macronutrient-focused Nutrition Facts panels or tables;
- Messaging about macronutrient attributes generally or specifically linked to positive health outcomes; and
- Rankings or scores in one or more qualitative systems governing how the food is grown, whether it is bio-engineered, vegan, or organic, and the degree and nature of food processing.

Most US and EU food product labels provide substantial information on macronutrient content. It is widely accepted that front-of-pact nutrition health messaging must be clear, simple, and support healthier food choices. Figure 2, as seen above, is an example of the new FOP graphics the FDA has under consideration that focus on macronutrient composition. Both options in Figure 2 draw upon the data in BOP Nutrition Facts panels. A graphic like those in Figure 2 belongs as part of enhanced FOP nutrition labeling. But the FDA's two options fall far short of accurately characterizing important differences in the nutritional quality across food products.

Future labeling should be augmented with clear, straightforward graphics, with some conveying the density of nutrients in a serving of food relative to caloric content (including health-linked micronutrients). Many people intuitively understand the need to seek out micronutrient-dense foods and healthier fats, but today's food labels too often obscure such choices when they should instead clarify and highlight them.

A third graphic is needed that focuses on the degree of processing (discussed below).

Progress on the dietary components of "personalized medicine" [48] will depend to some degree on whether and how future food labeling schemes provide information on aspects of food nutritional quality beyond macronutrient composition, and how food nutritional quality can be customized to reflect different recommended levels of nutrient intake across population cohorts dealing with different diet-related health problems.

Is there room for three graphics and/or crisp narrative messages conveying different aspects of food nutritional quality on the front of food package labeling? As noted in Section 3, FOP labeling on many food packages already contains 10 or more nutrient and nutrition-related messages, many of which are repeated elsewhere on the packaging. The overall impact of FOP labeling on purchase decisions would likely improve if fewer overall messages were delivered that are clearer, actionable, and more fully encompass the overall nutritional quality of the product, as opposed to single nutrients or attributes. In addition, such new labeling must not shy away from conveying the substantial variation in food nutritional quality across types of foods and across competing brands (e.g., potato chips baked in corn oil vs. pita chips baked in canola oil).

Figure 3 below provides an example of how the nutritional quality of a serving of food could be graphically conveyed in the case of the 2.94 NuCal value for Special K cereal (see Supplemental File: NuCal and Nutritional Quality Index (NQI) Values for 196 Foods in Three Zones Along the Nutritional Quality Continuum). This graphic, or variations of it, could include at the bottom "For further information: http//:xx.yy [QR code]". The link would open up a new tab with a more detailed version of the continuum including details on the source of the Special K NuCal value, how Special K compares to other similar cereals, and information on the percent of nutrients in Special K from the raw food ingredients in comparison to added supplemental nutrients.

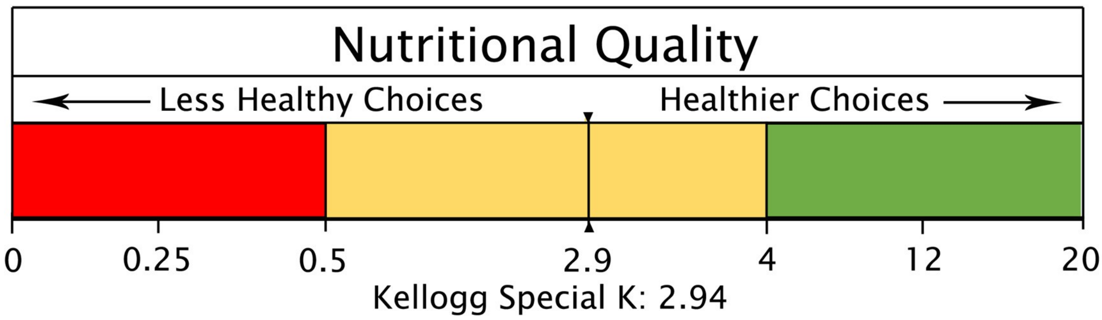


Figure 3. A Front-of-Pack Nutritional Quality Continuum Based on the NuCal Value for Special K Cereal.

4.1. Mostly New Challenges in Crafting Simple and Impactful Nutrition Labeling

Analytically, the percent of calories from a serving of a given food is already a part of the Nutrition Facts panel, so this half of the suggested NuCal metric will add no new costs or complexity for companies responsible for generating updated food labeling that adheres to the forthcoming FDA guidance.

Three other labeling challenges are important in terms of motivating and guiding changes in consumer food choices and are discussed below: (1) the degree of "wholeness" in a manufactured food product measured relative to the source of the nutrients in a food product, (2) calculating nutritional quality scores for multi-ingredient foods, and (3) new metrics needed for certain foods that reflect fat quality, and possibly other attributes or issues (e.g., nutrient balances or bioavailability).

The NuCal value for a multi-ingredient food will need to be calculated by quantifying the levels of the essential nutrients in a serving of the food. This process will add modestly to food companies' costs and burdens, since the levels of essential nutrients can be obtained from analytical labs that are already conducting extensive nutrient-specific testing to support information delivered via Nutrition Facts panels. A relatively small number of samples of multi-ingredient foods would need to be tested annually to confirm the continued accuracy of current nutrient levels in a serving of food.

The quality of the different fats in a serving of food is an important attribute with clear and substantial consequences on public health outcomes [45–47,49]. The best available metric to provide an indicator of fat quality is the ratio of omega-6 to omega-3 fatty acids in serving of food [50]. The metric could be based on deviation from a "desirable" or target an omega-6–omega-3 ratio (e.g., a ratio between 1:1 and 4:1 based on published research [51]). Such a metric will be especially valuable in assessing the differences in the nutritional quality of the following:

- Oils derived from olives, canola, corn, soybeans, sunflowers, linseed, or other oilseed crops, including differences across varieties of oilseed crops and production systems [52];
- Grass-fed versus mostly grain-fed cows [53,54], sheep, and chickens [55], and the products derived from them [56–58];
- Plant-based versus animal-derived meat, milk and dairy products, and eggs [59,60];
- Wild-caught versus farm-raised fish [61,62];
- Genetically engineered crops and foods derived from animals that are fed GMO feeds or supplements, or perhaps in the future, animals that are genetically altered through the tools of modern biotechnology.

Over time, challenges and new issues will emerge that require reaching agreement on changes in, for example, the nutrients included in calculations, applicable recommended intakes, or how the contribution of each nutrient is weighed in final scores. This process is ongoing in the EU and has recently led to changes in the Nutri-Score system ratings [63,64].

One additional advantage of the recommended approach for nutrition health-related labeling is that nutritional quality scores can be modified in light of the unique nutritional needs of specific population groups (e.g., pregnant women, individuals with GI tract problems) and/or the specific challenges different families and communities face in securing healthy foods. This can be carried out by developing population cohort-relevant adjustments to existing recommended nutrient intake levels, or novel ways to take account of nutrient balance or imbalances in nutritional quality metrics. Nutrient dense fruits and vegetables can be home grown, bought in season, and preserved. Advances in personalized nutrition and food is medicine recommendations to combat chronic diseases and overcome health problems rooted in nutrient deficiencies will be dependent on new ways to quantify the health-promoting potential of different foods and food brands based on their unique distribution of macro- and micronutrient levels.

Table 5 provides an overview of some of the ways nutrition-related guidance and recommendations can be made to consumers via food labels, as well as information portals that can encompass much more detailed discussion of issues, challenges, and possibly useful strategies to accelerate progress toward healthier diets.

Table 5. Providing information on smart choices, special needs, and food is medicine as an extension of new food labelling systems ($$ is dollars).

	Metrics	Applicable to	Foods High/Low in a Recipe	Other Considerations
Smart Choices				
More Nutrition Bang for the Buck	$$ spent per NuCal unit by serving	Representative foods in food category (e.g., salty snacks); specific products	$$ spent per NuCal unit by serving of food	Cost of garnishments or accompanying food
Dealing With Nutrient Deficiencies	Nutrient level per serving; Cost per serving	List of common nutrient deficiencies by population cohort	Target nutrients	Avoiding nutrient imbalances; nutrient availability
Strategies for the Winter	NuCal per serving	Perishable and seasonal foods	Target nutrients	Buying in bulk; storage options
Grow Your Own	Space per NuCal unit	Home gardens; in-house options	NuCal value	Family favorites; harvest period
Home Preservation	Safe use time period	Canned, dried, frozen, juices, sauces	NuCal value	Fulfil nutrient needs in winter, off-season
Spices and Ingredients to Boost Nutritional Quality	NuCal per gram/ounce	List of spices, garnishments	NuCal value	How to buy, store, and use high NuCal ingredients

Table 5. *Cont.*

	Metrics	Applicable to	Foods High/Low in a Recipe	Other Considerations
Special Needs				
Pregnancy	Pregnancy adjusted NuCal; TBD	Women pregnant, hoping to become pregnant	Most common nutrient deficiencies	Avoiding nutrient imbalances
Raising Small Children	Infant/child adjusted NuCal values	Families raising children	Most common nutrient deficiencies	Foods kids will eat; healthy snacks
Faith-Based	NuCal Value	Alternate recipes, food choices	Certain ingredients or	
Low-Income	$$ spent per NuCal unit by serving	Typical $$/NuCal unit for food product	High NuCal per dollar spent	Storage options; compatibility with family favorites
Meeting Nutrient Needs When Fresh Fruit and Vegetables are Scarce or Expensive	$$ spent per NuCal unit by serving of food	Preserved or processed fruit, vegetables, nuts, spices	NuCal vale	Food safety challenges; space for storage
Food as Medicine				
Allergies and Food Sensitivity	NuCal units of alternatives	Target list of common allergies	NuCal units per $$ by serving	
Diabetes and	Adjusted NuCal units	Target nutrients with links to CVD	Target nutrients	
Healthy Childhoods	See "Raising Small Children" Above			
GI Tract Ailments				
Combating Inflammation	Anti-inflammatory adjusted NuCal	Foods high in antioxidants	Antioxidant activity	Need for new ways to consume target foods
Sustaining Cognitive Function	Adjusted NuCal units	Foods with phytochemicals linked to brain health	Alternate factors leading to cognitive decline may require different nutrient-related interventions	

Results generated using alternate nutritional quality evaluation systems, and novel metrics like those noted in Table 5, can be made available by the FDA, food companies, and other entities (e.g., the American Dietetic Association) via websites, QR codes, and other means. Such an approach would also allow population subgroup-specific qualified health claims to be sought, approved by the FDA, and communicated via multiple channels. Otherwise, targeted "food is medicine" messages as part of "personalized medicine" would rarely be judged appropriate to appear as a Qualified Health Claim on food packages offered for sale to the general public.

4.2. Incorporating the Degree of Processing in Food Labeling

The identification of a robust and useful way to quantify the degree of processing is proving elusive [37–39]. Yet the degree of wholeness versus processing is an attribute of food many people care about and pay attention to. Multiple studies report substantial health degradation as consumption of heavily processed food increases (also known as UPF). For example, CVD risk was 7% lower for each 10% increase in plant-sourced, non-UPF intakes, while plant-sourced UPF increased CVD risk and mortality in an UK study [12]. In a study utilizing the NOVA food classification system in the lifelong cohort, a 10% increase in UPF consumption was associated with a 25% increase in risk of type 2 diabetes [21].

Based on the results of several published studies, the NOVA system works reasonably well at the extremes (fresh foods in contrast to heavily processed foods) but struggles to deal with multiple ingredient foods with varying degrees of processing and containing multiple food additives, e.g., [23]. In addition, some UPFs contain substantial nutrients and will score well in most nutrient profiling-based systems, especially if supplemental nutrients in fortified food ingredients and/or added to recipes are counted toward meeting daily nutritional needs.

Novel metrics should be considered in the search for a better way to quantify the degree of processing in a serving of food products. The reasons why consumers and scientists are concerned about the degree of processing should be taken into account in devising better ways to delineate the degree of processing. For many consumers concerned with food nutritional quality, a food brand with fewer chemical additives is generally preferrable, as are products in which most of the nutrients in the raw food ingredients remain in the food product as sold [65].

The factors going into the calculation of degree of processing metrics would vary across food groups and require food companies to conduct some additional tests on their ingredients and finished products as offered for sale. The results could be integrated in a number of ways to produce a metric encompassing the degree of wholeness versus alteration through processing. The values of such a metric could be placed along a continuum or reported as an index. A graphic depicting the degree of processing is presented in Figure 4. As in the case of the nutritional quality continuum graphic in Figure 3, the url and QR code at the bottom of Figure 4 could open a page with additional details on the derivation of the metric, the factors giving rise to the value for a specific food, and additional details such as the percent of nutrients in the product from the raw agricultural ingredients versus food additives, the total number of ingredients in the product, and comparisons to other products or food groups.

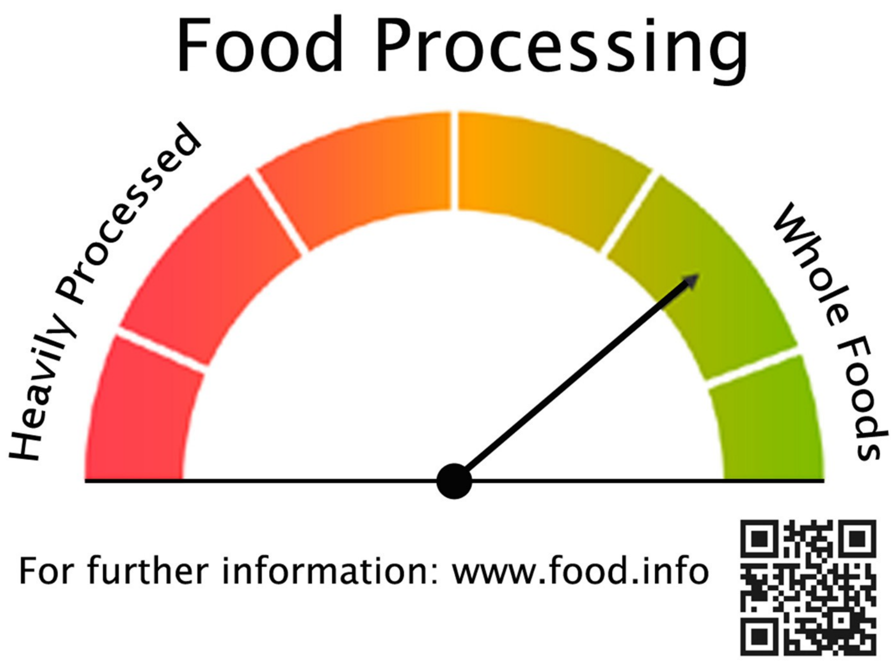


Figure 4. Food Processing Graphic for Placement on Front-of-Pack Labeling.

The graphic elements in Figures 3 and 4 can be combined in front-of-pack labeling in multiple ways. An integrated option is presented in Figure 5 that combines the nutritional quality and food processing graphics in Figures 3 and 4. As is the case with Figures 3 and 4, the url and QR code at the bottom of Figure 5 could provide access to an explanation of the metrics and how to interpret the information in the graphic, along with more detailed information about data sources and comparisons to other foods. It will take time, education, and consistent messaging from the government, food companies, and health-oriented institutions to help consumers understand what such graphics reflect. But the underlying concepts in such graphics must be grounded in data-driven metrics that accurately convey a food product's likely contribution, or lack thereof, to a healthy diet.

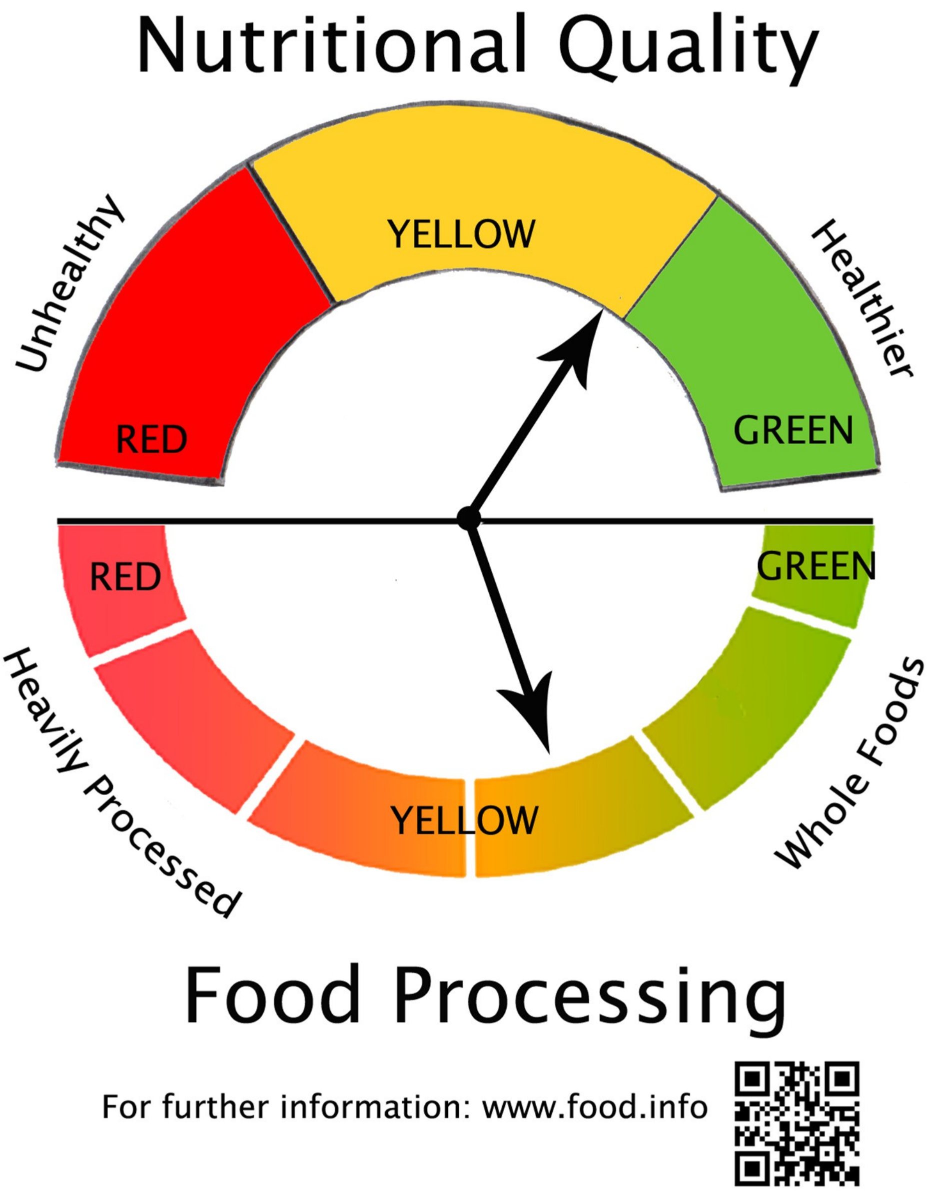


Figure 5. Conveying the Nutritional Quality and Degree of Food Processing in a Food Product in an Integrated Graphic.

4.3. Motivating Food Companies to Alter Recipes to Make Brand-Name Food Products Healthier

Improved content on front-of-pack and overall packaging that guides consumers toward healthier food choices will incrementally improve health outcomes. But more broad-based progress would be triggered, if, and as new, FDA-approved and mandatory nutrition-focused labeling begins to shift even a few percent of the market share from a brand to its competitors [66,67]. Such a shift would likely lead food manufacturers to review and modify recipes to improve how their brand name products fair in the new labeling scheme, thereby benefitting all consumers.

Like the campaigns deployed to discourage smoking or vaping among teenagers or the use of illegal drugs, government-sponsored public service announcements and related messaging should now be directed toward the need to improve public health via changes in food nutritional quality. A series of 30-s public service announcements informing consumers of the caloric space taken up by popular fast food meals would be an option.

The path ahead for the FDA in putting such a labeling system in place will be fraught with conflicting responses and challenges from food companies, the fast food industry, and commodity groups dedicated to advancing the sales of certain crops and foods. Some of those entities that anticipate benefits as a result of shifting consumer preferences will typically praise newly approved labeling options.

In response, the FDA, or whichever public or private entity decides to act to shift worrisome public health trends through more nutritious foods, will have to withstand substantial criticism and pushback. In the public square, the case will have to be made that there is sufficient information and knowledge today to make progress in what is emerging as this generation's most pressing public health challenge and opportunity.

5. Conclusions

Positive health outcomes will be achieved only if and as consumers eat more nutrient-dense fresh or minimally processed foods, coupled with fewer daily servings of heavily processed foods that deliver little or no nutrients despite prodigious caloric density.

Food package labeling should include clear and actionable information on the levels of macro- and micronutrients in a serving of different types of foods, and across brands within a food group. In addition, better information on the degree of processing will also help many consumers incrementally enhance the nutritional quality of daily dietary choices.

The effectiveness of food package labeling relative to promoting positive public health outcomes will depend on how the various components of nutrient and nutrition health-related labeling work together on food packaging in helping consumers identify better food choices. Focusing on one or a few nutrients or nutrition-health associations will always fall short of what is needed.

The new metrics described above will take time to design, vet, and implement. They will impose some additional, but modest, testing costs on the food industry, especially compared to advertising and marketing expenditures. The FDA will need to resolve a series of computation details in developing and deploying its version of a nutrient profiling system for use in quantifying food nutritional quality. The need for better data and more science will be universally accepted and will never end. Those who call for better information before the FDA or other governments act may, or may not, stymie progress that is clearly attainable now.

Consumer messaging could include a simple rule of thumb—for each serving of food that takes up significant caloric space and delivers modest nutritional value (i.e., red zone "junk food"), be sure to choose one or two servings of green zone super-foods. The possible societal return on investment in developing and deploying new food package labeling could be enormous, especially if and as rigorous and mandatory nutrition labeling motivates food manufacturers to alter recipes to avoid negative nutritional quality or food processing values, and further loss of market share.

Success will depend on a systematic, cohesive, and sustained effort among all stakeholders to work out technical details in ways that support clear and actionable guidance for consumers. Transparent and accurate food product-specific ingredient and nutrient composition data should determine the content of nutrition health labeling. Efforts to soften the message should be resisted in light of the overwhelming need for new food labels that help bring about substantial improvements in food nutritional quality and dietary choices.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/foods13213377/s1, Supplemental Tables S1–S18: Front-of-Pack and Back-of-Pack Nutrition and Health-Related Information, Claims, and Messaging on Nine Food Products in the US and the EU; Supplemental File: Methodology and Data Sources in Calculating Nutritional Quality Values for Specific Foods; Supplemental File: NuCal and Nutritional Quality Index (NQI) Values for 196 Foods in Three Zones Along the Nutritional Quality Continuum.

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