Nutritional Value Score rates foods based on global health priorities

Ty Beal (tbeal@gainhealth.org)
Global Alliance for Improved Nutrition (GAIN) https://orcid.org/0000-0002-0398-9825
Flaminia Ortenzi
Global Alliance for Improved Nutrition (GAIN)

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Ty Beal[1] and Flaminia Ortenzi[2]

[1] Corresponding author. Global Alliance for Improved Nutrition (GAIN). 1201 Connecticut Ave NW, Suite 700B-2, Washington, DC 20036, USA. Email: tbeal@gainhealth.org.

[2] Global Alliance for Improved Nutrition (GAIN). Rue de Varembé 7, 1202 Genève, Switzerland

Summary

Nutrient profiling systems are used to rate foods by nutritional value or healthfulness using food composition data. Each nutrient profiling system has different purposes and limitations[1–3]. Existing systems have not adequately addressed energy density and nutrient bioavailability[3–5]. Recent publications have also called for developing nutrient profiling systems for global use[2] and for assessing environmental impacts of foods[6]. To address these needs, we developed the Nutritional Value Score (NVS), which is based on nutrients of public health priority[7–12] and nutrient ratios predictive of noncommunicable disease risk[3,13]. The NVS adjusts for nutrient bioavailability and quantifies nutrient density in terms of Calories *and* grams, to address limitations in existing systems. Using common foods from Indonesia and Bangladesh as examples, the NVS effectively highlights nutritious items within recommended food groups. It also enables more nutritionally equivalent comparisons in environmental impact assessments. The NVS is a flexible tool for researchers, program implementers, and policymakers in varied contexts to identify healthy and sustainable foods. Although further validation is needed, initial testing suggests the NVS is an adaptable nutritional metric with diverse global applications.

Main

Nutrient profiling systems use food composition data to estimate nutritional value or healthfulness[1–3]. They are typically used to guide consumer choice, food policy, industry formulations, and investments. Popular implementations of nutrient profiling systems, including Nutri-Score in the European Union and Health Star in Australia and New Zealand, were developed in high-income countries with a focus on noncommunicable disease risk. Others like Food Compass[3] and the Nutrient Rich Foods index[4] have also been developed using data from high-income countries but aim to better capture risk for noncommunicable diseases *and* essential nutrient density. Each existing nutrient profiling system has strengths and limitations and is suitable for different purposes.

Food Compass[3] has notable strengths, including incorporating a wide range of dietary attributes reflective of healthfulness, like nutrient ratios, and validating against measures of diet quality, cardiovascular disease, and mortality[14]. However, it also has limitations. For instance, Food Compass only evaluates nutrient density per Calorie, which may underestimate the value of nutritious but energy-dense foods. It also includes some nutrients like phosphorus[15] and dietary cholesterol[16] that have limited public health relevance. Additionally, Food Compass scores do not account for differences in bioavailability of key nutrients like iron, zinc, and essential amino acids[5].

The Nutrient Rich Foods index[4] has strengths like excluding nutrients without public health relevance, offering adaptations for different uses, and validating against diet quality measures. However, it shares some limitations with Food Compass. For instance, it only evaluates nutrient density per Calorie and does not account for bioavailability differences in key nutrients. Additionally, the Nutrient Rich Foods index estimates noncommunicable disease risk using limiting nutrients, rather than nutrient ratios, which evidence suggests may better predict disease risk[3].

We developed a Nutritional Value Score (NVS) based on global health priorities to discriminate the nutritional value of foods recommended in global dietary guidelines[17]. We excluded fortified foods, due to a scarcity of reliable local food composition data, and ultraprocessed foods, because they are typically not the focus in dietary guidelines in Indonesia and Bangladesh. The NVS assesses the quantity and quality of essential nutrients as well as other dietary attributes that indicate protection against noncommunicable diseases. It is based on six components: vitamins, minerals, essential amino acids, *n*-3 fatty acids, fiber, and nutrient ratios. We also produced a Nutrient Density Score based solely on the four essential nutrient components, which can be used to identify nutrient dense foods to be targeted in policies and programs seeking to address essential nutrient deficiencies and associated undernutrition. The NVS and each component score is scaled from 1 to 100, where 1 is the food with the lowest nutritional value and 100 is the food with the highest. The NVS is intended to inform evidence-based policies and programs. It is also designed specifically for use in environmental impact and affordability assessments, which have difficulty incorporating nutritional differences in foods using common units like 1 kg or 1,000 Calories.

The NVS follows the latest scientific guidance on developing nutrient profiling systems for global use[2], food sustainability assessments[6], and affordability assessments[18]. The NVS also has unique features. It only includes essential nutrients of global health priority. Additionally, it adjusts for bioavailability of iron and zinc and measures the quantity *and* quality of essential amino acids, which vary considerably across foods. Moreover, the NVS quantifies nutrient density per unit mass *and* energy to account for the limitations in either approach when used in isolation. Further, it includes sub-scores for each nutritional component so that researchers, program managers, food producers, and policy makers can prioritize foods based on nutritional components of interest, making the NVS a flexible tool applicable across diverse contexts globally. While nutrient profiling systems have historically been focused on high-income countries, we developed the NVS using data from the US *and* two low- and middle-income countries, to ensure global relevance. Notably, the NVS was developed without industry funding, to minimize private sector influence and bias. And finally, all methods, data, and code are published open access so that other researchers can easily use, validate, and adapt the approach in other settings.

Component nutritional scores

We applied the NVS algorithm to common Indonesian and Bangladeshi foods from country-adapted Diet Quality Questionnaires (dietquality.org). Both countries face a double burden of undernutrition and noncommunicable diseases. Here we present the results for Indonesia as our main case study country, given the diversity of foods across and within food groups. Results for Bangladesh are available in the Supplementary Information.

No food scores high in all components. For example, spinach has the top mineral score (100) yet an *n*-3 score of just 24, while chicken organs have the top vitamin score (100) yet fiber and *n-3* scores of just 1 (Table 1). Foods with the highest vitamin scores are chicken organs, beef organs, and dark green leafy vegetables like spinach and drumstick leaves, while foods with the lowest vitamin scores include fruits like coconut and watermelon and certain starchy staples like rice, noodles, and pasta. Mineral scores are highest for dark green leafy vegetables like spinach and pumpkin leaves, chicken organs, and nuts and seeds like cashews and sunflower seeds, but are lowest for fruits like watermelon and apple, certain vegetables like tree fern and eggplant, as well as certain starchy staples like congee, rice, and cassava. Lean meats like boar and rabbit have the highest essential amino acids scores followed by other animal source foods and, to a lesser extent, soy products like tempeh, whereas starchy staples like cassava and corn have the lowest essential amino acids scores followed by fruits like apple and pear. Lastly, fish, bivalves, and crustaceans are the only high scoring foods in terms of *n*-3 content. Foods with the highest overall Nutrient Density Scores are organ meats, dark green leafy vegetables, and certain lean animal flesh foods like deer and bivalves, while the foods with the lowest Nutrient Density Scores are primarily starchy staples and fruits.

For fiber, the food with the top score is rose apple followed by beans and seeds like mung beans and sunflower seeds, while the lowest fiber scores are attributed to animal source foods, congee, certain fruits like watermelon and snake fruit, as well as oncom and soy milk. Most foods score highly on nutrient ratios since they are foods recommended in dietary guidelines, excluding ultraprocessed foods. The lowest scoring food is congee followed, to a much lesser extent, by nuts and seeds, other starchy staples like brown rice cakes and cassava, certain fruits like snake fruit and coconut, as well as cheese and oncom.

Nutritional Value Scores

The NVS can be used to compare the nutritional value of foods both within and across foods groups. Across food groups, the highest NVSs are seen for dark green leafy vegetables, organ meats, lean meats, bivalves, fish, and crustaceans (Table 1, Fig. 1). On the other end of the spectrum, the lowest scores belong to starchy staples like congee and cassava, fruits like watermelon and apple, and certain vegetables such as eggplant and cucumber. Scoring relatively high, typically between 40 and 70, are other vegetables including zucchini and pumpkin; legumes, nuts, and seeds; animal-source foods like beef, pork, eggs, chicken, and dairy; as well as certain starchy staples like sweet potato and fruits like rose apples, guavas, and avocados.

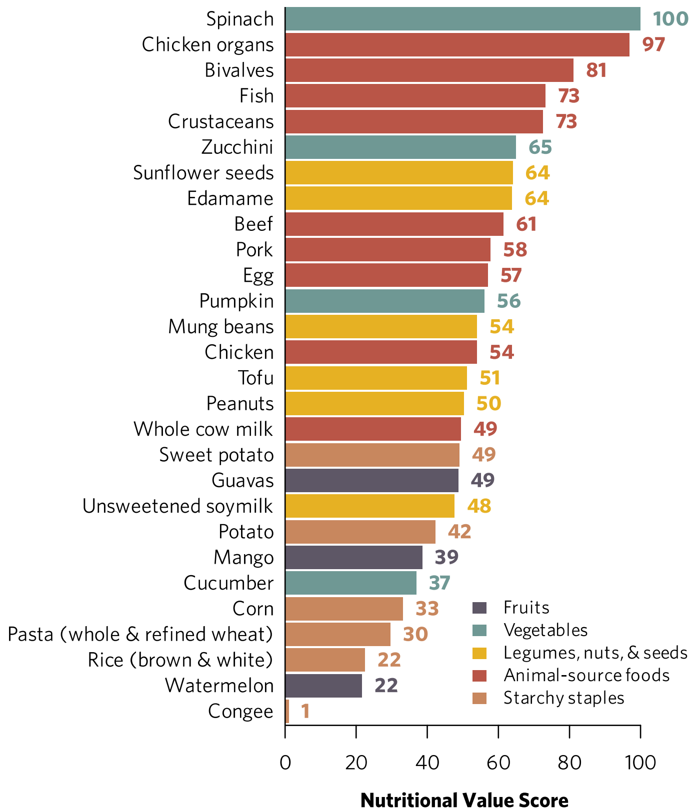

Fig. 1 | Nutritional Value Scores for common Indonesian foods. The Nutritional Value Score rates foods by nutritional value. It is scaled from 1 (lowest) to 100 (highest).

The NVS also shows large variation between foods within the same food group. For vegetables, the NVS ranges from 33 to 100, with dark green leafy vegetables having the highest scores and eggplant, cucumber, and cauliflower having the lowest scores (Fig. 2). Other vegetables fall in the middle, with a NVS between 40 and 70. Similarly, there is some variation within the fruit category, with the NVS ranging from 22 for watermelon to 50 for rose apple (Supplementary Fig. 1). For legumes, nuts, and seeds, the range is narrower, from

42 for oncom to 64 for sunflower seeds and edamame (Supplementary Fig. 2). Animal source foods show wide variation as well, with the NVS ranging from 45 for duck to 97 for chicken organs (Supplementary Fig. 3). Finally, among starchy staples the NVS ranges from just 1 for congee up to 49 for sweet potato (Supplementary Fig. 4). In summary, while there is some variation within each food group, the extent differs, with vegetables and animal-source foods showing wider NVS ranges compared to fruits; legumes, nuts, and seeds; and starchy staples.

Results from the sensitivity analyses for the NVS algorithm are presented in the Supplementary Material.

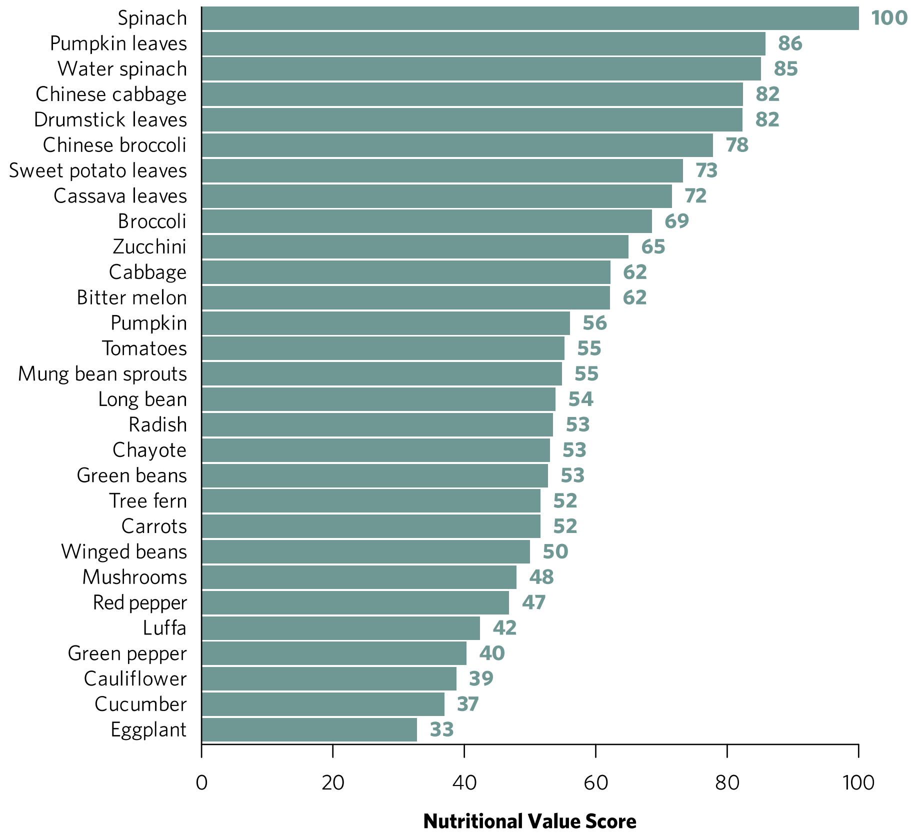

Fig. 2 | Nutritional Value Scores for common Indonesian vegetables. The Nutritional Value Score rates foods by nutritional value. It is scaled from 1 (lowest) to 100 (highest).

Implications for life cycle analysis

Environmental life cycle analyses typically assess the environmental impacts of foods in terms of kgs. However, such practices fail to account for variation in nutritional value across and within food groups. Within vegetables, for example, cucumber has a lower nutritional value than spinach (Fig. 1)—yet a typical environmental impact assessment would equate 1 kg of cucumber to 1 kg of spinach. Comparing foods in terms of Calories also inadequately accounts for nutritional differences. Within fruits, for example, watermelon has a lower nutritional value than mango (Fig. 1)—yet a typical environmental impact assessment would equate 1,000 Calories of watermelon to 1,000 Calories of mango.

The NVS offers a better way to assess environmental impacts of foods by measuring the nutritional value produced and standardizing it for comparisons within and across food groups. To illustrate, just 231 g of spinach is needed for a NVS of 100 whereas 626 g of cucumber is needed to achieve the same NVS (Fig. 3). It is also more appropriate to compare mango and watermelon using a fixed NVS rather than a fixed number of Calories. For example, just 778 Calories of mango is needed for a NVS of 100 whereas 1,389 Calories of watermelon is needed to achieve the same NVS (Supplementary Fig. 11).

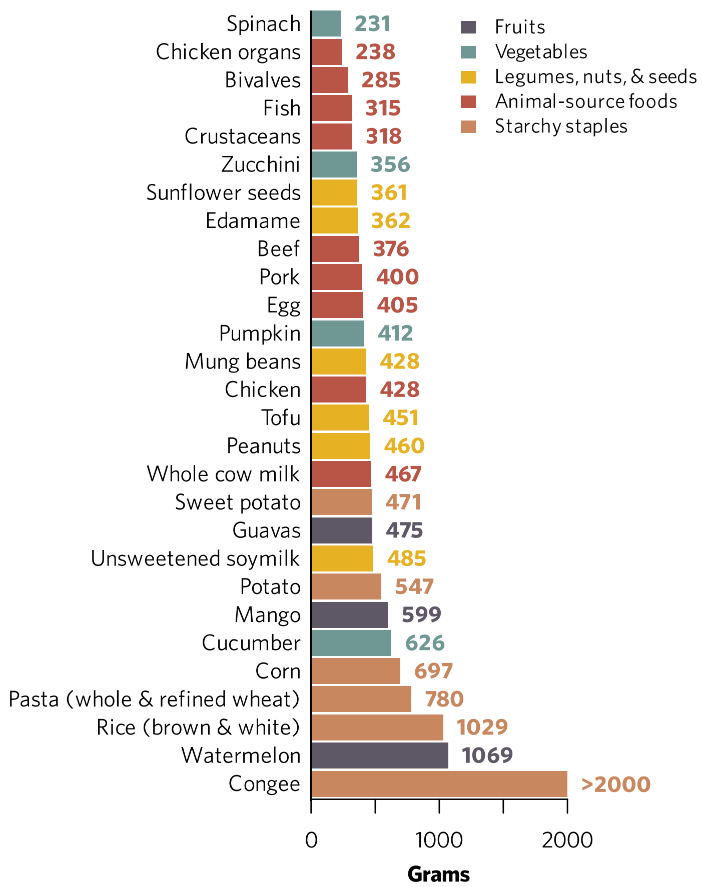

Fig. 3 | Grams of Indonesian foods needed for a Nutritional Value Score of 100. The Nutritional Value Score rates foods by nutritional value. It is scaled from 1 (lowest) to 100 (highest).

Discussion

The NVS and its component scores are useful for guiding policies and programs and can be tailored for target populations like women and young children. It complements food-based dietary guidelines because it discriminates the nutritional value of foods within commonly recommended food groups: fruits; vegetables; legumes, nuts, and seeds; animal source foods; and starchy staples[17]. Therefore, policy makers and program implementers can prioritize promoting and increasing access to the most nutritious foods within each food group to achieve greater health impacts.

The NVS is also designed for use as a functional unit in life cycle assessments to estimate environmental impacts per unit nutritional value. Identifying better options for such assessments is essential, as current practices vary widely[6], with no scientific consensus[19], and results tend to be unit-dependent[20]. For example, a landmark global environmental impact meta-analysis used functional units of mass, energy, and total protein content[21]. A more recent study[23] used this data along with updated environmental data on aquatic foods[22] and nutritional quality as assessed by the nutrient profiling system, Nutri-Score. Other researchers have used nutritional functional units based on nutrient density, for example as assessed by variations of the Nutrient Rich Foods index[24] or by priority micronutrient value[25]. The NVS, complemented by local food, nutrition, and environmental impact data, where available, can be used to compare the environmental impact of foods across or within food groups. Assessing environmental impacts per fixed NVS places foods on nutritionally equivalent footing, improving upon prior metrics by incorporating aspects of priority nutrient density and protection against noncommunicable diseases. Food-based dietary guidelines could include the resulting insights to encourage consumption of context-appropriate sustainable healthy diets.

The NVS is also designed for use in food affordability assessments. Affordability of single foods has been assessed per unit energy[26], priority micronutrient value[27], and by the Nutrient Rich Foods index[18]. As with life cycle assessments, the NVS provides a more comprehensive way to standardize foods by nutritional value for food affordability assessments. Application of the NVS in food affordability assessments would provide insights to aid social protection programs in identifying the most affordable food sources of nutrition. Demand creation programs could focus on increasing consumer demand for the most affordable nutritious foods; at the same time, policies could help reduce the price of unaffordable nutritious foods, for example, by providing agricultural incentives, limiting the role of intermediaries in supply chains, improving infrastructure, and taking measures to counterbalance inflation[28].

To determine initial validity and robustness of the NVS, we assessed content validity and face validity and conducted various sensitivity analyses. We ensured content validity of the NVS algorithm through inclusion of dietary attributes of global health priority, comprising essential nutrients of public health concern[7–11] and dietary factors that indicate protection against noncommunicable diseases[3,12,13]. We tested face validity by implementing the NVS algorithm across recommended local foods available in Indonesia and Bangladesh, two disparate countries with a high burden of malnutrition. Finally, we conducted sensitivity analyses of different component weights, micronutrient capping, and winsorizing to test the robustness of the NVS to various assumptions and parameters.

We were not able to assess convergent and discriminant validity since the NVS was developed to discriminate between foods recommended in global dietary guidelines. If the NVS was adapted and implemented across a broader range of foods, including ultraprocessed foods, then convergent and discriminant validity could be assessed. However, we caution against overreliance on validation of nutrient profiling systems against existing diet quality metrics, like the Healthy Eating Index, in which high scores can be achieved with over 90% of Calories from ultraprocessed foods[29]. This is because rigorous evidence from a randomized controlled trial found that a diet consisting of 80% of Calories from ultraprocessed foods led to substantial overeating and weight gain compared to a diet containing mostly unprocessed foods, even though meals within both diets were matched for presented Calories, macronutrients, sugar, sodium, and fiber[30]. Moreover, Healthy Eating Index scores have increased[31] alongside the obesity epidemic in the US, further calling into question the suitability of the Healthy Eating Index for validation of nutrient profiling systems through observational study designs[32].

Future research could test the NVS for criterion validity in diverse contexts, including correlating the NVS with essential nutrient biomarkers, noncommunicable disease markers, and mortality. Validation using nutritional epidemiology, however, is limited due to confounding and various forms of bias, which can be difficult or impossible to properly adjust for[33]. Therefore, we recommend validating the NVS using randomized controlled trials which, when designed appropriately, account for both known and unknown confounders.

The NVS has many strengths. It follows recommendations for developing nutrient profiling systems for global use[2] by solely using essential nutrients of global health priority, analyzing locally available, commonly consumed foods, and offering flexibility for adaptation to country-specific contexts or populations. The NVS also uses nutrient ratios, which recent evidence suggests may identify noncommunicable disease risk more accurately than simply using limiting nutrients[3]. Moreover, the NVS follows best practices for developing nutrient profiling systems for use in environmental impact assessments[6]. Further, the NVS assesses the quantity *and* quality of essential micronutrients and macronutrients, including adjustments for nutrient bioavailability. Importantly, the NVS quantifies nutrient density in terms of mass *and* energy, which ensures foods are not unfairly penalized or benefited for having low or high Calorie density. Finally, the NVS offers nutritional component scores to provide more granular insights for researchers, policy makers, and program managers. These strengths make the NVS more suitable than existing systems for global health applications in low- and middle-income countries.

The NVS also has some limitations. It was developed for foods recommended in global dietary guidelines. If the NVS is to be used across a broader range of foods, including those not recommended in dietary guidelines, it may need to be adapted. Additionally, while many bioactive compounds have health benefits, we did not include them as a dietary attribute because food composition data only exists for certain phytochemicals highest in plant source foods and not bioactive compounds unique to animal source foods. We chose to exclude phytochemicals to avoid biasing the bioactive compound attribute against animal source foods. We also were unable to include dietary attributes related to fermented foods, since food composition data indicating beneficial microorganisms is lacking. Additionally, our necessary reliance on USDA datasets for some dietary attributes may lead to neglecting important differences in varieties, production methods, soil conditions, and culinary traditions that exist between the US and other countries under investigation. Finally, we assessed the NVS for content validity and face validity, but it has not yet been assessed for construct or criterion validity. Future studies could adapt the NVS for broader applications and assess its validity using epidemiology and randomized controlled trials.

The NVS provides a comprehensive metric to assess and compare the overall nutritional value of foods and specific nutritional components of interest, like micronutrients and essential amino acids. It captures multiple dietary components critical for global health and has many unique features that make it suitable for global applications. The NVS can be used to help policymakers and program implementers identify nutritious foods to prioritize for the greatest health impacts. Additionally, using the NVS as a functional unit could allow for more nutritionally equivalent comparisons in environmental impact and affordability assessments of foods. Further adaptations for a broader set of foods and validation studies are warranted, but the NVS shows promise for a range of diverse applications to advance healthy and sustainable food systems.

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Tables

Table 1 | Nutritional scores for common Indonesian foods

Food	Vitamin score	Mineral score	EAA score	n-3 fatty acid score	Fiber score	Nutrient ratio score	Nutrient Density Score	Nutritional Value Score
Spinach	79	100	45	24	56	99	96	100
Chicken organs	100	72	83	1	1	95	100	97
Beef organs	86	59	85	2	1	94	88	88
Pumpkin leaves	65	72	50	14	72	100	76	86
Water spinach	68	73	42	23	54	99	77	85
Deer	64	65	92	2	1	97	82	84
Chinese cabbage	62	71	40	34	38	99	74	82
Drumstick leaves	77	66	49	6	27	97	77	82
Bivalves	39	63	68	91	2	94	74	81
Chinese broccoli	62	60	40	20	60	100	66	78
Goat	42	61	88	2	1	99	68	75
Buffalo	53	43	93	2	1	100	66	73
Fish	50	21	77	100	2	94	63	73
Sweet potato leaves	54	55	47	8	62	99	60	73
Horse	40	56	94	5	1	95	67	73
Crustaceans	42	40	77	64	2	95	63	73
Cassava leaves	50	65	41	6	31	99	62	72
Broccoli	60	42	37	12	54	99	55	69
Dove	41	54	75	13	1	91	62	68
Boar	41	35	100	6	1	97	59	67
Rabbit	43	36	96	5	1	93	59	67
Zucchini	47	51	34	15	32	99	52	65
Sunflower seeds	55	69	42	3	77	51	66	64
Edamame	32	45	54	17	53	100	48	64
Cabbage	43	43	34	14	49	99	46	62
Bitter melon	37	50	33	13	56	99	46	62
Beef	35	48	78	3	1	86	55	61
Lamb	38	42	78	2	1	87	54	60
Red beans	30	35	40	20	81	99	39	59
Pork	44	26	84	5	1	83	51	58

Food	Vitamin score	Mineral score	EAA score	n-3 fatty acid score	Fiber score	Nutrient ratio score	Nutrient Density Score	Nutritional Value Score
Egg	51	18	63	14	1	94	46	57
Pumpkin	45	40	32	1	20	96	43	56
Tomatoes	39	35	32	15	27	98	40	55
Tempeh	17	42	60	14	35	93	40	55
Mung bean sprouts	37	38	39	1	25	97	40	55
Mung beans	22	28	44	19	81	99	32	54
Chicken	29	25	78	13	1	92	42	54
Long bean	30	40	37	7	30	97	38	54
Radish	26	42	33	1	49	99	35	53
Chayote	31	35	33	1	56	99	34	53
Green beans	33	27	34	9	59	99	33	53
Tree fern	46	3	48	8	63	99	31	52
Carrots	38	24	35	1	51	98	33	52
Tofu	7	43	54	16	17	98	35	51
Cheese	22	44	81	4	1	67	48	51
Peanuts	40	55	32	2	67	51	48	50
Rose apple	28	14	32	18	100	100	25	50
Plain whole yogurt	22	25	60	12	1	100	34	50
Winged beans	10	51	44	4	19	93	36	50
Whole cow milk	27	20	58	10	1	100	33	49
Sweet potato	32	18	52	1	31	96	32	49
Whole milk powder	23	22	59	10	1	100	33	49
Whole sheep milk	25	19	63	7	1	100	33	49
Guavas	32	21	27	4	69	99	27	49
Mushrooms	34	24	33	1	29	98	30	48
Unsweetened soymilk	18	17	54	45	7	93	31	48
Red pepper	47	10	30	1	23	98	29	47
Cantaloupe	36	21	25	14	18	94	30	46
Duck	26	23	64	1	1	83	35	45
Cashews	16	76	28	2	25	47	46	44
Peanut butter	34	48	29	2	50	49	41	43
Avocado	23	18	26	5	63	97	21	43
Papaya	28	17	24	11	28	96	23	42
Luffa	16	24	31	7	35	97	22	42

Food	Vitamin score	Mineral score	EAA score	n-3 fatty acid score	Fiber score	Nutrient ratio score	Nutrient Density Score	Nutritional Value Score
Oncom	1	53	48	14	7	71	35	42
Potato	16	20	52	3	21	93	25	42
Orange	27	13	25	11	37	97	21	42
Durian	29	15	25	8	37	94	22	41
Green pepper	29	8	30	6	23	98	20	40
Starfruit	18	10	28	15	56	99	16	40
Taro	17	19	25	3	50	95	17	39
Cauliflower	29	9	31	1	21	94	20	39
Mango	31	7	25	9	22	94	19	39
Grapefruit	24	10	25	14	22	96	18	38
Breadfruit	13	17	26	3	48	96	15	38
Tangerine	22	11	24	10	27	96	17	38
Snake fruit	26	35	25	10	6	64	31	37
Cucumber	9	22	31	9	12	95	18	37
Pineapple	24	8	25	10	22	94	17	37
Banana	15	15	25	4	30	95	15	36
Longan	26	9	25	5	16	91	17	36
Unsalted brown rice cakes	16	38	26	2	34	60	26	34
Green banana	14	18	26	4	17	87	16	34
Corn	14	14	17	3	29	95	12	33
Eggplant	14	7	29	4	23	94	12	33
Coconut	1	20	27	4	72	76	11	30
Pear	2	4	24	13	43	97	4	30
Pasta (whole & refined wheat)	5	13	24	2	28	91	8	30
Apple	2	2	24	17	35	97	4	29
Dragon fruit	2	4	26	5	43	97	3	29
Noodles (rice & wheat)	4	11	20	2	25	93	5	28
Rice (brown & white)	2	5	21	1	14	86	2	22
Watermelon	2	1	24	3	5	87	1	22
Cassava	11	8	1	2	18	80	3	21
Congee	6	2	35	3	3	1	7	1

Methods

Nutritional Value Score

The NVS aims to capture the variation in nutritional value across moderately processed foods recommended in global dietary guidelines, including fruits; vegetables; legumes, nuts, and seeds; animal-source foods; and starchy staple foods. The NVS assesses the quantity and quality of essential nutrients as well as other dietary attributes that protect against noncommunicable diseases. It is scaled from 1 and 100, where 1 is the food with the lowest nutritional value and 100 is the food with the highest. The NVS is the weighted average of six normalized dietary attribute scores: vitamins (25%), minerals (25%), essential amino acids (15%), *n*-3 fatty acids (10%), fiber (5%), and nutrient ratios (20%). We selected these attributes based on their global health priority and availability across diverse foods in existing food composition databases.

Global diets are commonly lacking in essential vitamins, minerals, amino acids, and *n*-3 fatty acids[7–11]. We established their relative weights in the NVS based on the global prevalence and severity of health consequences of inadequacy and deficiency, and on the number of nutrients included in the attribute. The vitamins and minerals attributes make up 50% of the NVS because deficiency in one or more of four micronutrients is prevalent in over half of preschool-aged children (iron, zinc, and vitamin A) and two thirds of women of reproductive age (iron, zinc, and folate), causing substantial public health burden[8]. Moreover, estimated dietary inadequacies of numerous single micronutrients also show high prevalence worldwide[10,11]. We weighted the essential amino acids attribute 10 percentage points lower than the vitamins and minerals attributes because deficiency in essential amino acids is less prevalent but still poses a public health challenge globally[9]. We weighted the *n*-3 fatty acids attribute 15 percentage points lower than vitamins and minerals attributes because, while two thirds of adults are estimated to have low intake of DHA and EPA and one fifth are estimated to have inadequate intake of ALA[7], the *n*-3 attribute includes just one essential nutrient while the vitamins, minerals, and essential amino acids attributes each include multiple essential nutrients.

We weighted the fiber attribute 20 percentage points lower than the vitamins and minerals attributes. This is because, although inadequate fiber intake is common worldwide[12], fiber is not an essential nutrient. Also, like the *n*-3 attribute, fiber is the only component within the attribute. Additionally, the NVS assesses moderately processed foods recommended in dietary guidelines and thus do not substantially contribute to risk of noncommunicable diseases that fiber protects against. We weighted the nutrient ratios attribute five percentage points lower than the vitamins and minerals attributes. Although nutrient ratios are important for assessing risk of noncommunicable diseases[3,13], the NVS focuses on foods that pose minimal overall risk when consumed within dietary guidelines.

Each dietary attribute is described in further detail below.

Vitamins

The vitamin score (V) reflects the quantity and quality of 11 vitamins of public health priority: folate, choline, riboflavin, thiamin, niacin, and vitamins A, B6, B12, C, D, and E. Low supply, low intake, or deficiency of these vitamins is common worldwide[8,10,11]. V is the average of two sub scores—VE and VM—each normalized between 1 and 100. VE reflects the vitamin density per unit energy. VM reflects the vitamin density per unit mass. Scoring foods per unit energy *and* mass ensures foods low in energy or mass are not unduly favored in the overall score. *VE* is calculated as follows:

$$VE_i = \frac{1}{A} \sum_{a \in A} \min \{ve_{a,i},\ 1\}$$

where *ve* is the proportion of recommended nutrient intakes (RNIs) for each of the 11 vitamins (*A*) provided in 300 Calories of each food (*i*). Each vitamin's contribution to *VE* per 300 Calories was capped at the RNI to prevent foods very high in one vitamin from inflating the score. Although the chosen reference amount is arbitrary (as for all nutrient profiling systems), 300 Calories corresponds to about 13% of average energy requirements for moderately active individuals[34], which represents a relatively plausible amount of energy to obtain from a single food in one day (except for low-Calorie foods).

VM is calculated the same as *VE* but per 231 g of each food. This quantity was calculated by dividing 300 Calories by 1.3 Calories/g (the mean energy density of a minimally processed plant-based, low-fat diet and an animal-based, ketogenic diet)[35].

Minerals

The mineral score (*M*) reflects the quantity and quality of five minerals of public health priority: iron, zinc, calcium, potassium, and magnesium. Low supply, low intake, or deficiency of these minerals is common worldwide[8,10,11]. *M* is the average of two sub scores—*ME* and *MM*—each normalized between 1 and 100. *ME* reflects the mineral density per unit energy. *MM* reflects the mineral density per unit mass. *ME* is calculated as follows:

$$ME_i = \frac{1}{A} \sum_{a \in A} \min \{me_{a,i}, 1\}$$

where *me* is the proportion of RNIs for each of the five minerals (A) provided in 300 Calories of each food (i). Each mineral's contribution to *ME* per 300 Calories was capped at the RNI to prevent foods very high in one mineral from inflating the score. Iron and zinc contents were adjusted for bioavailability following Beal and Ortenzi (2022)[36].

MM is calculated the same as *ME* but per 231 g of each food. This quantity was calculated by dividing 300 Calories by 1.3 Calories/g (the mean energy density of a minimally processed plant-based, low-fat diet and an animal-based, ketogenic diet)[35].

Essential amino acids

The Essential Amino Acids score (*EAA*) reflects the quantity and quality of essential amino acids. *EAA* is the average of two sub scores—*eaa* and *DIAAS*—each normalized between 1 and 100. *eaa* is the average of the sum of the essential amino acids per 300 Calories (*eaaE*) and the sum of essential amino acids per 231 g (*eaaM*). *DIAAS* is the untruncated Digestible Indispensable Amino Acids Score (DIAAS).

n-3 fatty acids

The *n*-3 score (*n3*) reflects the quantity and quality of *n*-3 fatty acids. *n3* is the average of two sub scores—*n3E* and *n3M*—each normalized between 1 and 100. *n3E* reflects the *n*-3 fatty acid density per unit energy. *n3M* reflects the *n*-3 fatty acid density per unit mass. *n3E* is calculated as follows:

$$n3E_i = max(DHA_i + EPA_i + DPA_i, ALA_i)$$

where *DHA+EPA+DPA* and *ALA* indicate the proportion of RNIs of long chain (250 mg) and short chain (1,240 mg) *n*-3 fatty acids, respectively, provided in 300 Calories of each food (*i*). *n3M* is calculated the same as *n3E* but per 231 g of each food.

Fiber

The fiber score (*F*) reflects the quantity of fiber. *F* is average of two sub scores—*FE* and *FM*—each normalized between 1 and 100. *FE* is the quantity of fiber in 300 Calories of each food. *FM* is the quantity of fiber in 231 g of each food.

Nutrient ratios

The nutrient ratios score (*NR*) reflects the increased risk for noncommunicable diseases from consuming foods high in carbohydrates and low in fiber, high in sodium and low in potassium, and high in Calories[3,13]. *NR* is the average of three negative sub scores each normalized between 100 and 0: *CFR*, *NaKR*, and *EMR*. *NR* is normalized between 1 and 100. *CFR* is the carbohydrate:fiber ratio. We assigned zero *CFR* values to animal source foods containing no added sugar or starch, since naturally occurring carbohydrates in animal source foods are not associated with health risk[37]. *NaKR* is the sodium:potassium ratio. We assigned zero *NaKR* values to foods containing <0.9 mg sodium/Calorie, in alignment with the World Health Organization's recommendations for adults to limit daily sodium intake to <2,000 mg (assuming an average energy requirement of 2227 kcal for moderately active individuals[34]). *EMR* is the energy:mass ratio. We assigned zero *EMR* values to foods containing <1.3 Calories/g.

Liquid dairy and dairy alternatives

For unsweetened milk, kefir, and semi-liquid yogurts, including plant-based varieties, we based the scores for *V*, *M*, *eaa*, *n3*, and *F* exclusively on *VE*, *ME*, *eaaE*, *n3E*, and *FE*, respectively, since they are low in Calories, and their mass is not a barrier to consumption as it is with solid foods. We scaled powdered milk to the same energy density as liquid milk, so that it would be analyzed in the form typically consumed.

Nutrient Density Score

The Nutrient Density Score reflects the overall quantity and quality of essential nutrients of public health priority. The Nutrient Density Score is normalized between 1 and 100 where 1 represents the food with the lowest nutrient density and 100 represents the food with the highest nutrient density. The Nutrient Density Score is the weighted average of four normalized dietary attribute scores: vitamins (35%), minerals (35%), essential amino acids (20%), *n*-3 fatty acids (10%).

Software

All analyses were conducted using R version 4.3.1.

Food composition data

We built two food composition databases: one for Indonesia and one for Bangladesh, with values for Calories, carbohydrates, fiber, mono and polyunsaturated fatty acids, saturated fatty acids, 11 vitamins, 6 minerals, short and long chain *n*-3 fatty acids, essential amino acids, DIAAS, and phytate[38]. Nutrient densities were primarily obtained from USDA databases[39], complemented by the Indonesian and Bangladeshi food composition tables for local foods which were not available in USDA databases[40]. Values for DIAAS were obtained from the literature, by prioritizing studies conducted in humans, followed by those conducted in pigs and, as a third option, rats, and by preferring average over single values when available.

We included all unprocessed, minimally processed, and processed foods recommended in dietary guidelines globally[17]. These are the sentinel foods listed in the country-adapted Diet Quality Questionnaires for Indonesia and Bangladesh (dietquality.org), which ensure our analysis focused on locally available, commonly consumed foods. We compiled data on the composition of foods as they are usually eaten, whether raw, cooked, or both. Where applicable and where data were available, nutrient values for multiple cooking methods for the same food were averaged. In addition, for meat, nutrient densities for various cuts and portions of the same animal were averaged. With regards to aggregate sentinel foods (for example, fish, cheese, rice), food composition data from different species or varieties were collected and averaged (for example, fish species popular in Indonesia or Bangladesh, types of hard and soft cheese, different varieties and levels of refinement of rice).

Missing values for individual foods were replaced by the corresponding average values for all foods within a given Diet Quality Questionnaire question. For instance, if the vitamin E density of water spinach (question 6.1 in the Diet Quality Questionnaire for Indonesia) was missing, the average value for all vegetables under question 6.1 would be used, assuming that foods belonging to the same Diet Quality Questionnaire question have comparable food composition. This approach allowed us to fill all data gaps except for ALA, whose value was only available for a limited set of foods in USDA databases, and for which we sometimes had to rely on available literature.

For more details on the food composition data, please refer to the Supplementary Material.

Dietary reference intakes

For vitamins and minerals, we used harmonized nutrient reference values, which recommend a mix of values from the European Food Safety Authority and the Institute of Medicine, depending on the micronutrient (Supplementary Tables 1–2)[41]. For *n*-3's we used European Food Safety Authority RNIs.

Sensitivity analyses

We conducted three sensitivity analyses. First, we capped vitamin and mineral contents at 50% and 200% of the RNI. Second, we shifted the weights of dietary attributes towards protection against noncommunicable disease: *V* (10%), *M* (10%), *EAA* (10%), *n3* (20%), *F* (20%), *NR* (30%); and nutrient density: *V* (30%), *M* (30%), *EAA* (20%), *n3* (10%), *F* (5%), *NR* (5%). Third, we winsorized the NVS by truncating outliers at the 5th and 95th percentiles.

Data Availability

All data are publicly available in cited references and in the Extended Data.

Code Availability

All code will be made available on GitHub before the time of publication.

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Author contributions

T.B and F.O developed the theory and methods and co-wrote the manuscript.

Competing interest declaration

The authors declare no competing interests.

Supplementary Files

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