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Food Compass 2.0 is an improved nutrient profiling system to characterize healthfulness of foods and beverages

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Food Compass is a nutrient profiling system used to assess the healthfulness of diverse foods, beverages and meals. Here we present a revised version of Food Compass (Food Compass 2.0) incorporating new data on specific ingredients and the latest diet–health evidence. Food Compass 2.0 has been validated against health outcomes in a population from the United States and demonstrates enhanced ability to characterize foods and beverages based on their healthfulness.

The escalating health burdens of diet-related non-communicable diseases require population-level strategies. Nutrient profiling systems (NPSs), quantitative algorithms that evaluate and rank healthfulness of foods and beverages, are increasingly common tools for governments and industry to make decisions around promoting healthier eating, including for front-of-pack and menu labelling, thresholds to restrict food marketing, eligibility for health claims, food procurement policies, portfolio reformulation targets, and health-conscious investment strategies[1–3].

Many existing NPSs have important limitations, including a focus on mostly negative nutrients, lack of assessment of many food ingredients or emerging nutrients of relevance, omission of processing characteristics, inconsistent scoring across food categories and for mixed products and meals, and scoring per food weight (confounded by water content). To address these challenges, the Food Compass was developed in 2021 as an NPS that captures nine holistic domains of product characteristics, including components such as nutrient ratios as indicators of fat, carbohydrate and mineral quality; food ingredients of greatest health relevance; and food processing, phytonutrient and additive characteristics—all per 100 kcal (ref. 4). Previous investigations demonstrated that the Food Compass facilitates a more balanced and universal assessment of foods and beverages with uniform scoring criteria to minimize subjectivity, enhance consistency, and score mixed foods and meals; has strong validity against other common NPSs; associates with improved health risk factors and prevalent disease conditions; and independently predicts total mortality when applied to diets of individuals[4,5].

At the same time, as a highly promising NPS, Food Compass was intended to be reviewed and improved based on emerging evidence, availability of new data and scientific feedback from the community. In this report, we present our methods, results and validation to develop Food Compass 2.0 as an improved NPS.

Details of the specific updates as part of Food Compass 2.0 are provided in Supplementary Table 1. A comparison of the original Food Compass versus Food Compass 2.0 across the 9,273 unique food and beverage items showed similar mean Food Compass scores (FCSs) for some major food groups (for example, nuts, legumes, sauces/condiments), but meaningful shifts in others (Supplementary Fig. 1 and Supplementary Table 2). Among food subgroups, notable FCS declines (mean ± SD) included cold cereals (from 51 ± 21 to 41 ± 20), plant-based dairy (54 ± 21 to 43 ± 20), cereal bars (42 ± 16 to 34 ± 15), and fruit and vegetable juices (from 72 ± 15 to 66 ± 14); while increases included beef (33 ± 6 to 44 ± 6), pork (35 ± 8 to 44 ± 9), seafood (72 ± 14 to 81 ± 14), lamb and game (39 ± 8 to 49 ± 8), eggs (46 ± 13 to 54 ± 13), and rice and pasta (43 ± 26 to 49 ± 23) (Fig. 1 and Supplementary Table 3). Within these subcategories, changes at the individual food level varied. For example, within eggs, the FCS of a whole egg fried without fat increased from 48 to 62, whereas egg substitute decreased in score from 50 to 45 (other examples in Supplementary Table 4). The original Food Compass versus Food Compass 2.0 scores for all 9,273 foods and beverages are provided in Supplementary Table 5.

Among all products, 23% scored FCS ≥70 (previously 22%); 46%, FCS 31–69 (previously 46%); and 31%, FCS ≤30 (previously 33%); but

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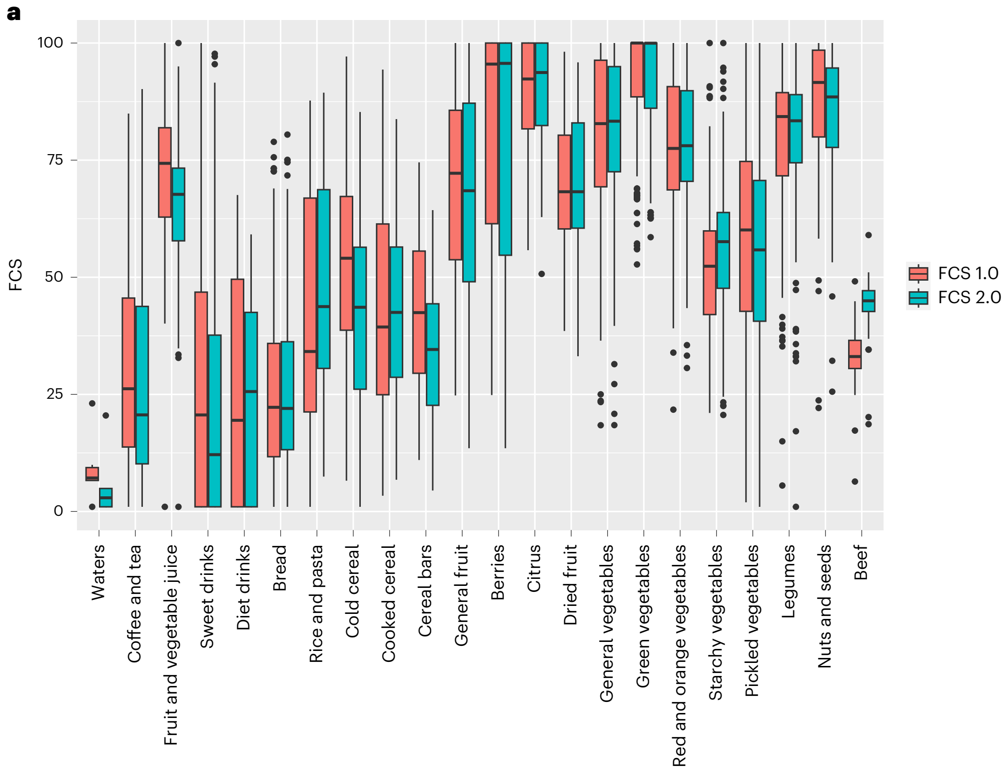

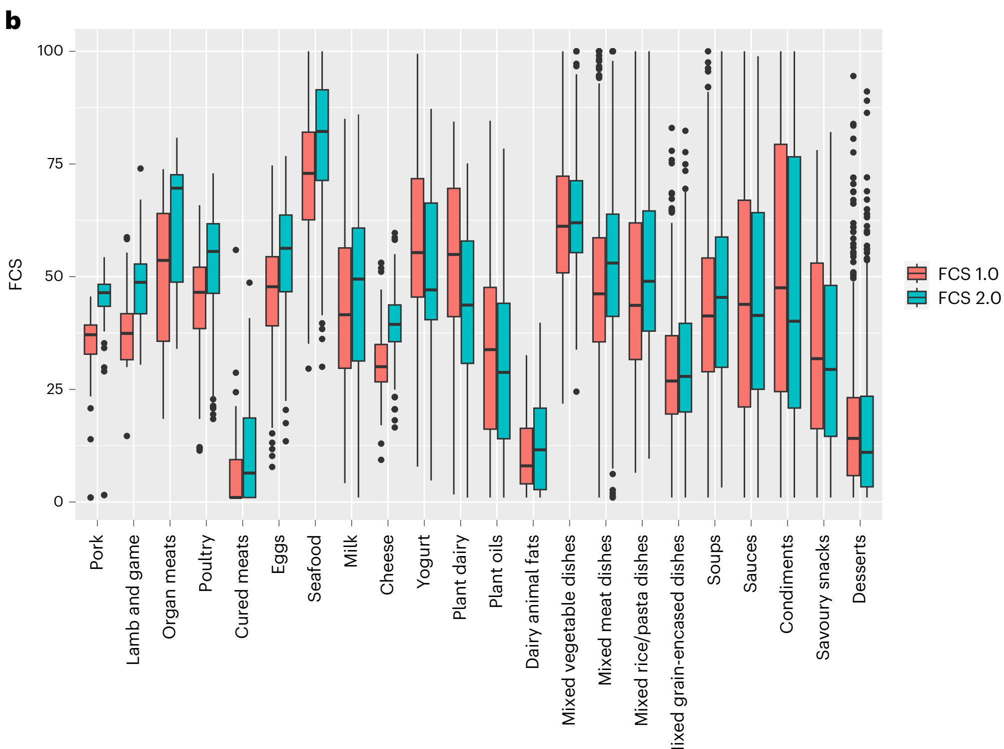

Fig. 1 | Updated and original FCSs for products consumed by US adults. **a**,**b**, Data are from 9,273 products reported within NHANES 2001/02–2017/18 for subcategories 1–22 (**a**) and 23–44 (**b**). Standard box plots are shown, with horizontal lines representing the median value, bounds of boxes representing the 25th (lower bound) and 75th (upper bound) percentile values, whiskers representing 1.5 × interquartile range from the 25th percentile (for the lower whisker) and the 75th percentile (for the upper whisker), and the black dots beyond these bounds representing outliers.

with meaningful variation by food category (Fig. 2). For example, most beverages (54%) and animal fats (92%) scored ≤30; whereas most meat, poultry, eggs and dairy scored 31–69 (52%, 91%, 89% and 73%, respectively). Most products within seafood, legumes, nuts, vegetables and fruits scored ≥70 (82%, 80%, 89%, 63% and 53%, respectively; with lower-scoring items often including high added sugars or other additives).

Compared to other common NPSs such as Health Star Rating (HSR), Nutri-Score or NOVA processing classification, Food Compass 2.0 demonstrated meaningful overlap but also further important

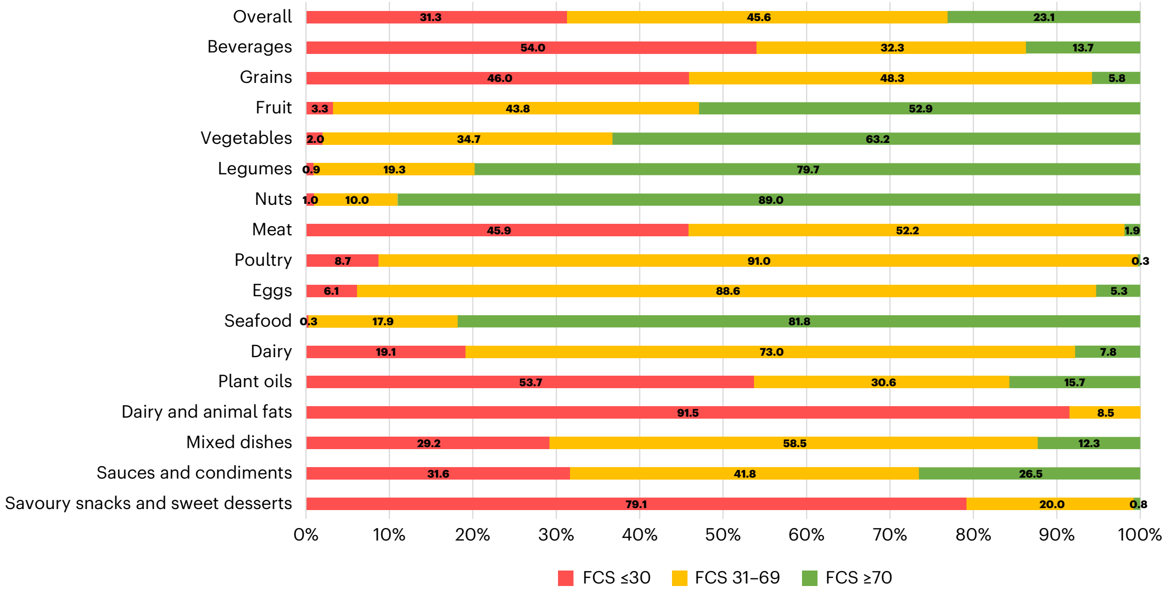

Fig. 2 | Percentages of FCSs ≤30, 31–69 and ≥70. Foods and beverages scoring ≤30 are those to be minimized, foods and beverages scoring 31–69 are those to be consumed in moderation, and foods and beverages scoring ≥70 are those to be encouraged. The major food groups meat, poultry, eggs, fats and oils, and legumes and nuts have been split to show detail. Meat includes beef, pork, lamb and game, organ meats, and cured meat.

differentiation (Supplementary Fig. 2 and Supplementary Table 5). For example, among products with the highest HSR (5.0), 82% had FCS ≥70, but product scores ranged from 100 for chia seeds to 60 for low-fat cottage cheese to 10 for fat-free margarine. Among products with the lowest HSR (0.5), 86% had FCS ≤30, but product scores included 84 for dried shrimp, 26 for cooked pork bacon and 1 for chocolate-covered caramel candy. Similarly, within NOVA group 1, 49% of products had FCS ≥70, but scores ranged from 100 for raw blackberries to 59 for rotisserie chicken breast with skin to 12 for rice noodles. Within NOVA group 4, 68% of items had FCS ≤30, but scores ranged from 87 for low-fat fruit yogurt to 53 for flavoured instant oatmeal to 1 for cola-flavoured soft drink. Compared to the original Food Compass, Food Compass 2.0 still exhibited substantial discrimination against HSR, Nutri-Score and NOVA (Supplementary Table 6). Intercorrelations became modestly more concordant between Food Compass 2.0 and NOVA for all categories, such as for grains (previously $r = 0.07$, now $r = 0.31$) and dairy (from 0.31 to 0.58), and between FCS 2.0 and HSR for grains (from 0.27 to 0.42) and legumes, nuts and seeds (from 0.46 to 0.55); and modestly less concordant for fats and oils (from 0.47 to 0.36). Given the high correlation between Nutri-Score and HSR ($r = 0.83$), the strength and direction of changes in concordance of Food Compass against Nutri-Score were similar to those for HSR.

Food Compass 2.0 also performed well when the scores of individual food products were extended to score the daily diets of individuals and then validated against health outcomes. In a nationally representative population of 47,099 US adults, the energy-weighted average FCS of foods and beverages consumed was calculated for each person (referred to as i.FCS). The mean score was 36.6 ± 10.8, consistent with a relatively poor average diet. The i.FCS correlated highly with HEI-2015 ($r = 0.78$), a validated measure of a healthy dietary pattern. After multivariable adjustment, each 1 s.d. (10.8 points) higher i.FCS was associated with more favourable body mass index (−0.56 kg m^{-2} (95% confidence interval (CI) −0.65, −0.47)), systolic blood pressure (−0.55 mm Hg (95% CI −0.77, −0.34)), diastolic blood pressure (−0.46 mm Hg (95% CI −0.63, −0.29)), low-density lipoprotein cholesterol (−1.49 mg dl^{-1} (95% CI −2.10, −0.87)), high-density lipoprotein cholesterol (1.61 mg dl^{-1} (95% CI 1.41, 1.81)), total cholesterol to high-density lipoprotein ratio (−0.12 (95% CI −0.13, −0.10)), haemoglobin A1c (−0.02% (95% CI −0.02, −0.01)) and fasting plasma glucose (−0.36 mg dl^{-1} (95% CI −0.67, −0.05)); and with a lower prevalence of metabolic syndrome (odds ratio (OR), 0.86; 95% CI, 0.83, 0.89), cardiovascular disease (OR, 0.92; 95% CI, 0.88, 0.96), cancer (OR, 0.93; 95% CI, 0.89, 0.98) and lung disease (OR, 0.90; 95% CI, 0.87, 0.94); and higher prevalence of optimal cardiometabolic health (OR, 1.22; 95% CI, 1.14, 1.30) (Supplementary Table 7). The updated i.FCS also associated with lower all-cause mortality (per 1 s.d., hazard ratio, 0.92; 95% CI, 0.88, 0.95) and with a 24% lower risk in the highest i.FCS quintile versus the lowest (hazard ratio, 0.76; 95% CI, 0.68, 0.84) (Supplementary Fig. 3 and Supplementary Table 8).

These findings present an updated, validated Food Compass NPS. Maintaining the strengths of the core principles and framework, these modifications better reflect the scientific evidence on processing, added sugar, dietary fibre, dairy fat, artificial additives and trace lipids. One impactful update was providing positive points for non-ultraprocessed foods, rather than only negative points for ultraprocessed foods. Accumulating scientific evidence demonstrates the health benefits of minimally processed foods[6,7], and Food Compass 2.0 therefore better distinguishes products across the range of food processing for both animal- and plant-source foods. Similarly, Food Compass 2.0 better accounts for research suggesting the relatively neutral health effects of dairy fat[8,9]; and for harms of added sugar as not just an additive but also a food ingredient[10]. Notably, although artificial additives were attributes in the original Food Compass, data for their scoring were not previously available, which has now been rectified. Consequently, scores of highly processed foods with multiple artificial additives have decreased. These changes provide FCS values that more appropriately reflect dietary guidelines for their consumption.

Although individual items in any category had specific changes in their score, in general, Food Compass 2.0 provides higher scores for minimally processed animal foods such as seafood, dairy, meat, poultry and eggs; and lower scores for processed cereals, beverages, flavoured yogurts, and processed plant-based egg, meat and dairy alternatives. At the same time, few products (~10%) had a score change exceeding 10 points, highlighting the relative stability of the Food Compass framework and its principles. Food Compass 2.0 also provides important differentiation within categories of processing; for example, blueberries (FCS 100) and white rice (FCS 23) are both NOVA type 1, but their substantially different nutritional effects are appropriately reflected in their FCS. Although scores of starch-rich refined staples such as white rice or bread are low when consumed alone, Food Compass 2.0 allows scoring of mixed meals and provides higher scores to recipes that integrate starchy staples with other healthful ingredients. This supports alignment of Food Compass with both modern nutrition science and with diverse food cultures that value traditional dietary patterns. In conclusion, the updated Food Compass demonstrates improved ability to characterize foods and beverages based on healthfulness, with continued discrimination against existing NPSs, and demonstrated validity against healthful dietary patterns and health outcomes. We encourage researchers, policymakers, retailers, manufacturers and all stakeholders interested in identifying and encouraging healthier food and beverages to use Food Compass 2.0 (the full algorithm for its calculation is presented in the Supplementary Information). Given the foundational principles of Food Compass and the global reach of many packaged foods, we expect Food Compass 2.0 to have validity in many contexts, as has been shown already in Greece[11], Korea[12] and China[13]. We are also engaging in collaborative efforts to adapt Food Compass for use in different world regions, which could include adapting certain scoring parameters to align with regional differences in food supply. We hope that the holistic nature and demonstrated validity of Food Compass encourage food manufacturers to measure and report more of the important attributes in the scoring. At the same time, we are also developing and evaluating adaptations of Food Compass to be scored from a smaller set of more commonly available nutrient and ingredient information, leveraging imputation and estimation techniques, to facilitate scoring of all products in the marketplace with currently available data.

Methods

Because this study used deidentified, publicly available data from the National Health and Nutrition Examination Survey (NHANES), institutional review board approval was not required. The NHANES protocol was approved by the institutional review board at the National Center for Health Statistics, with all participants providing informed written consent. Participants were also compensated and received a report of their medical findings.

Detailed methods are presented in Supplementary Methods 1 and 2. Briefly, we compared the original and updated FCS for 9,273 unique foods and beverages in a nationally representative dataset, assessing face validity, convergent and discriminant validity, and criterion validity including associations with health outcomes. Key updates include (1) broader discrimination in scoring of food processing; (2) inclusion of added sugar, a major potential energy source, in the food ingredients domain; (3) higher scoring weight for dietary fibre as a positive attribute; (4) lower scoring weight for dairy fat as a negative attribute; and (5) new data collection on additives (for example, artificial sweeteners) which were in the original algorithm but previously unscored due to insufficient data. Other updates included neutral scoring for fruit and vegetable juice as food ingredients; and greater scoring weight to long-chain omega-3 fatty acids as compared to other lipids. Details of these revisions and their rationales are provided in Supplementary Table 1. Details of the scoring process for each attribute, domain and the overall FCS are provided in Supplementary Tables 9 and 10. By design, FCSs are scaled to range from 1 (least healthy) to 100 (most healthy). Although scores can be considered continuously, general recommendations have also been proposed at FCS ≥70 (foods to be encouraged), FCS 31–69 (foods to be consumed in moderation) and FCS ≤30 (foods to be minimized)[4,5], which may be useful when strict cut-offs for healthy and unhealthy products are required.

Reporting summary

Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

Data availability

The attribute- and domain-scoring algorithm used to generate Food Compass is available in Supplementary Tables 9 and 10. All data used in this analysis are publicly available from the following US Department of Agriculture (USDA) and Centers for Disease Control sources: (1) nutrient composition data for foods reported in NHANES dietary recalls (USDA Food and Nutrient Database for Dietary Studies 2001–2018, https://www.ars.usda.gov/northeast-area/beltsville-md-bhnrc/beltsville-human-nutrition-research-center/food-surveys-research-group/docs/fndds-download-databases/); (2) food ingredients data for foods reported in NHANES dietary recalls (USDA Food Pattern Equivalents Database, 2001–2018, https://www.ars.usda.gov/northeast-area/beltsville-md-bhnrc/beltsville-human-nutrition-research-center/food-surveys-research-group/docs/fped-overview/); (3) flavonoid data for select foods reported in NHANES dietary recalls (USDA Flavonoid Database, 2007–2010, ars.usda.gov/northeast-area/beltsville-md-bhnrc/beltsville-human-nutrition-research-center/food-surveys-research-group/docs/fndds-flavonoid-database/); (4) national dietary recall, sociodemographic, physical activity, smoking, cardiometabolic biomarker and prevalent condition data for US adults (NHANES 1999–2018, wwwn.cdc.gov/nchs/nhanes/Default.aspx); (5) all-cause and cause-specific mortality data for US adults (National Death Index 1999–2018, https://www.cdc.gov/nchs/data-linkage/mortality-public.htm). The Nutri-Score categorizations for each food and beverage were calculated using the 2023 updated algorithm[14]. The Health Star Rating values for each food and beverage were calculated using the publicly available online calculator and guidance: www.healthstarrating.gov.au/internet/healthstarrating/publishing.nsf/Content/excel-calculator, www.healthstarrating.gov.au/internet/healthstarrating/publishing.nsf/Content/guide-for-industry. The generated Food Compass, HSR, Nutri-Score and NOVA food-processing classification scores for each of the 9,273 food items in the dataset are available in Supplementary Table 5.

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Author contributions

All authors had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. D.M., J.B.B. and R.M were responsible for the concept and design of the analysis. E.M.B. and P.S. conducted data and statistical analyses. E.M.B. and D.M. drafted the paper. P.S., J.B.B., M.O., R.M. and D.M. critically reviewed the paper for its intellectual content. D.M. obtained funding and supervised the entire body of work.

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Competing interests

J.B.B. reports personal fees from Guiding Stars Licensing Company, outside of the submitted work. D.M. reports scientific advisory board, Beren Therapeutics, Brightseed, Calibrate, Elysium Health, Filtricine, HumanCo, Instacart Health, January, Season Health, Validation Institute, WndrHlth; and stock ownership in Calibrate and HumanCo, all outside the submitted work. The other authors declare no competing interests.

Additional information

Supplementary information The online version contains supplementary material available at https://doi.org/10.1038/s43016-024-01053-3.

Correspondence and requests for materials should be addressed to Eden M. Barrett.

Peer review information *Nature Food* thanks Maira Bes-Rastrollo, Priscila Machado, and the other, anonymous, reviewer(s) for their contribution to the peer review of this work.

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Reporting Summary

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For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

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☐	☒	A description of all covariates tested
☐	☒	A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons
☐	☒	A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals)
☐	☒	For null hypothesis testing, the test statistic (e.g. F, t, r) with confidence intervals, effect sizes, degrees of freedom and P value noted *Give P values as exact values whenever suitable.*
☒	☐	For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings
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☒	☐	Estimates of effect sizes (e.g. Cohen's d, Pearson's r), indicating how they were calculated

Our web collection on statistics for biologists contains articles on many of the points above.

Software and code

Policy information about availability of computer code

Data collection	All data was downloaded directly from sources specified in data availability statement. No software was used for data collection.
Data analysis	Custom code was developed using R (4.3.1) and Stata SE (Version 18.0) for data cleaning, adjustments, algorithm scoring for FCS 2.0 for individual food and beverage items, cross-sectional analyses comparing FCS 2.0 to HSR, Nutri-Score, and NOVA, i.FCS 2.0 scoring for individuals, cross-sectional and survival analyses of i.FCS 2.0 with health outcomes, and summary statistics, tables, and figures. Statistical significance was defined as two-tailed alpha=0.05. Tufts University is considering licensing of expertise, knowledge, and background work for potential commercial viability of Food Compass for the private sector and non-profit applications, and thus the code is not publicly available. There are no intellectual property or patent protections associated with Food Compass. The detailed Food Compass algorithm and its scoring are specified in our earlier Nature Food publication, with all updates and modifications described in the current supplementary materials (Table S9 and S10), and can be freely reproduced by any individual or organization.

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Portfolio guidelines for submitting code & software for further information.

Data

Policy information about availability of data

All manuscripts must include a data availability statement. This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A description of any restrictions on data availability
- For clinical datasets or third party data, please ensure that the statement adheres to our policy

The attribute and domain scoring algorithm used to generate the Food Compass 2.0 is available in Supplementary Table S9 and S10. All data used in this analysis is publicly available from the following USDA and CDC sources: (1) Nutrient composition data for foods reported in NHANES dietary recalls [USDA Food and Nutrient Database for Dietary Studies 2001-2018, FNDDS: https://www.ars.usda.gov/northeast-area/beltsville-md-bhnrc/beltsville-human-nutrition-research-center/food-surveys-research-group/docs/fndds-download-databases/]. (2) Food ingredients data for foods reported in NHANES dietary recalls [USDA Food Pattern Equivalents Database, 2001-2018: https://www.ars.usda.gov/northeast-area/beltsville-md-bhnrc/beltsville-human-nutrition-research-center/food-surveys-research-group/docs/fped-overview/]. (3) Flavonoid data for select foods reported in NHANES dietary recalls [USDA Flavonoid Database, 2007-2010: ars.usda.gov/northeast-area/beltsville-md-bhnrc/beltsville-human-nutrition-research-center/food-surveys-research-group/docs/fndds-flavonoid-database/. (4) National dietary recall, sociodemographic, physical activity, smoking, cardiometabolic biomarker, and prevalent condition data for US adults [National Health and Nutrition Examination Survey 1999-2018, NHANES: wwwn.cdc.gov/nchs/nhanes/Default.aspx (5) All-cause and cause-specific mortality data for US adults [National Death Index 1999–2018, NDI: https://www.cdc.gov/nchs/data-linkage/mortality-public.htm. The Nutri-Score categorizations for each food and beverage were calculated using the 2023 updated algorithm (Merz et al. Nat Food 2024). The Health Star Rating values for each food and beverage were calculated using the publicly available online calculator and guidance: www.healthstarrating.gov.au/internet/healthstarrating/publishing.nsf/Content/excel-calculator, www.healthstarrating.gov.au/internet/healthstarrating/publishing.nsf/Content/guide-for-industry. The generated Food Compass 2.0, HSR, Nutri-Score and NOVA food processing classification scores for each of the 9,273 food items in the dataset are available in Supplementary Table S5.

Human research participants

Policy information about studies involving human research participants and Sex and Gender in Research.

Reporting on sex and gender	NA
Population characteristics	NA
Recruitment	NA
Ethics oversight	NA

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

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Behavioural & social sciences study design

All studies must disclose on these points even when the disclosure is negative.

Study description	Quantitative, cross-sectional and prospective analysis using secondary data from publicly available USDA and CDC databases
Research sample	For individual food and beverage score FCS analysis, we applied the original and updated (2.0) Food Compass algorithm to 9273 unique foods and beverages reported in the National Health and Nutrition Examination Survey (NHANES) from the years 2001-02 to 2017-18, contained within FNDDS 2001-02 to 2017-18. We excluded infant formula, baby foods, specialized dietary foods, alcohol, and products providing <5 kcal per 100g as these products are not intended to be scored using Food Compass. For i.FCS analysis, we used a nationally representative sample of US adults 1999-2018 (n=47,999) from the National Health and Nutrition Examination Survey (NHANES) from 99/00 to 17/18. Study sample size was determined by NHIS staff to allow for a nationally representative sample. We included all NHANES respondents in the dietary portion of the survey, with a few exceptions as outlined in the exclusion section. This sample was chosen to ensure we are validating Food Compass 2.0 for use with foods and beverages consumed by the US population over the past two decades.
Sampling strategy	Sampling procedures including sample size calculation conducted by NHIS staff for NHANES, detailed here: https://wwwn.cdc.gov/nchs/nhanes/analyticguidelines.aspx#sample-design Since 1999, the sample design has consisted of multi-year, stratified, clustered four-stage samples, with data release in 2-year cycles.

	The NHANES sample is drawn in four stages: (a) PSUs (counties, groups of tracts within counties, or combinations of adjacent counties), (b) segments within PSUs (census blocks or combinations of blocks), (c) dwelling units (DUs) (households) within segments, and (d) individuals within households. PSUs are sampled from all U.S. counties. Screening is conducted at the DU level to identify sampled persons (SPs), based on oversampling criteria. NHANES 2015-2018 oversampled some subgroups to increase precision for subgroup estimates.
Data collection	Data collection was conducted by NHIS staff for NHANES. Secondary data for the present analysis come from the Household interview, MEC Medical Examination including two 24-hour dietary recalls. NHANES gathers broad health and nutrition data for various public health purposes. The data is intended for multiple uses by different researchers with their own hypotheses. Thus, data collectors are not blinded because there are no specific hypotheses to be blinded against. More details provided here: www.cdc.gov/nchs/data/series/sr_01/sr01_056.pdf
Timing	Data is collected continuously throughout the year but released in 2-year intervals (each release being nationally representative).
Data exclusions	We excluded NHANES respondents without valid dietary recalls (n=7434), extreme total energy intake (<500 or >5000kcal/d n=704), who only reported intake of alcoholic beverages (n=3), or with missing data on smoking status (n=34). For prospective mortality analyses we also excluded participants without valid linked mortality data (n=81).
Non-participation	Data on response rates for NHANES surveys for each 2-year survey cycle can be found here: wwwn.cdc.gov/nchs/nhanes/ResponseRates.aspx#response-rates.
Randomization	Participants were not allocated into experimental groups.

Reporting for specific materials, systems and methods

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Materials & experimental systems

n/a	Involved in the study	
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Methods

n/a	Involved in the study	
☒	☐	ChIP-seq
☒	☐	Flow cytometry
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