


SHORT COMMUNICATION OPEN ACCESS

Micronutrient Density of the Global Food Supply

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ABSTRACT

Global diets are inadequate in micronutrients, leading to deficiencies and related diseases. Addressing these micronutrient shortfalls requires increasing the nutrient density of the global food supply. Inferring micronutrient supply based on food balance sheet data is widespread practice in nutrition modelling, whereas designing food-based interventions is usually done using dietary data. Here, we provide an online interactive tool for investigating the micronutrient density of food balance sheet items, to help identify appropriate food supply interventions to increase the availability of micronutrient-dense foods globally. While the tool can be used for up to 28 food components (including macronutrients), we demonstrate its use by ranking food balance sheet items based on their combined content of 17 micronutrients per 100 g or per 100 kcal. High ranking foods varied between the mass and energy lists, but included offals, seeds, nuts, seafood, and non-starchy vegetables. The tool can be used by nutrition researchers to identify foods with the potential for supplying the specific combinations of micronutrients needed by at-risk populations.

1 | Introduction

Inadequate micronutrient intakes and deficiencies are widespread worldwide (Beal et al. 2017; Passarelli et al. 2022; Passarelli et al. 2024; Stevens et al. 2022). The total impact on human health and productivity is difficult to quantify, given the common existence of comorbidities, but it is universally agreed that there is urgency in addressing micronutrient deficiencies to achieve sustainable healthy diets and food systems (Development Initiatives 2020; Hendriks et al. 2021).

Various strategies exist to address poor micronutrient intakes, including supplementation and food fortification. However, improving diets via the prioritization of nutrient dense foods is a relatively low regulation, low intervention approach that can avoid some of the challenges around poor consumer acceptability, lack of broad implementation, and regulatory requirements that

can hinder fortification and supplementation programs (Bailey et al. 2015; Clermont et al. 2018; Embling et al. 2024). Consuming nutrients through inherently nutrient dense foods also has nutritional benefits due to the complex nature of the food matrix and the thousands of compounds that make up foods (Barabási et al. 2020).

Knowing which foods should be prioritized to address inadequate micronutrient intakes is not straightforward. Inadequacies can vary widely between countries, regions, and individuals. For example, it has been shown that usual intakes of selenium, sodium, zinc, and phosphorus vary significantly between sexes even in the same country and age group (Passarelli et al. 2022). Thus, while there exist metrics that rank foods based on their content of micronutrients often consumed in inadequate quantities (Beal and Ortenzi 2022), these do not allow for easy tailoring to specific combinations of insufficiencies.

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For studying national and global nutrient supply, the FAO Food Balance Sheets (FBS) (FAO 2024) are often used as a data source (Lividini and Masters 2022; M. R. Smith et al. 2016; N. W. Smith et al. 2021). A common goal of this research is to understand what foods should be targets for increased production, waste reduction, and consumption to address insufficient nutrient supply. There is therefore value in understanding the micronutrient density of FBS items to further these efforts.

Here, we present a nutrient density tool focusing on FBS items. The tool allows for the ranking of food items based on their content of any combination of up to 28 macro- and micronutrients, as well as a visualization of which nutrients contribute to the ranking and to what extent. The tool is accessible through an existing food system model—the DELTA Model—available at www.sustainablenutritioninitiative.com. To indicate the utility of the tool, we here relate its use in ranking FBS items based on their density of 17 essential vitamins and minerals.

2 | Methods

To assess the micronutrient density of FBS items, we leveraged the existing work underpinning the DELTA Model (N. W. Smith et al. 2021). The DELTA Model is a freely accessible online tool that calculates nutrient availability against global population requirement of current and possible future food system scenarios. Its methodology is fully described in the original publication, but the relevant aspects are included here.

In the construction of the DELTA Model, FBS items were matched to food composition data from the U. S. Department of Agriculture (USDA 2020) to determine their composition. It is notable that FBS item names are often vague or encompass many food items; for example, “Vegetables, other.” In these instances, a weighted average of component foods was used to represent the FBS item, with weightings derived from various FAO and global food databases, as described in the original publication and visible in the DELTA Model interface.

Nutrient reference values were obtained from the European Food Safety Authority (European Food Safety Authority 2017). Seventeen vitamins and minerals were common across both the nutrient reference values and the composition data, and thus chosen for display here: calcium, copper, iron, magnesium, phosphorus, potassium, selenium, zinc, and vitamins A, B1 (thiamin), B2 (riboflavin), B5 (pantothenic acid), B6, B9 (folate), B12, C and E.

For the calculation of the nutrient density metric, we compared the nutrient composition of FBS food items to the nutrient requirements of a 35-year-old female, given the relatively high micronutrient requirements of this demographic group compared to others. Other nutrient requirements were also tested, but this had a negligible impact on item rankings and scores. The proportional contribution of either 100 g or 100 kcal of each FBS item to each nutrient requirement was calculated, and then summed for each FBS item across all included nutrients, with equal weighting given to each nutrient. Finally, the resulting values were normalized, giving each FBS item a score from 1 to 100 for ease of interpretation. When collecting FBS items into food

groups for visualization, the groupings of the DELTA Model were used (see Supporting Information 1).

It was noted that “Fish; Liver Oil” received a score more than double that of the next FBS item when the score was calculated on a mass basis, solely due to its vitamin A content, which was above the safe upper intake limit for a 35-year-old female in both 100 g and 100 kcal of oil. Due to its outlier nature and lack of relevance as a broadly micronutrient dense food, “Fish; Liver Oil” was omitted from the analysis. Similarly, “Coffee and products,” “Tea (including mate),” and “Cottonseed” are not practical solutions for addressing micronutrient deficiency, so they were also omitted.

3 | Results

Whether the score was calculated on a mass or energy basis had important implications for which FBS items achieved the highest scores. Figure 1 shows the scores for the top 20 food items from each calculation (Figures S1 and S2 show the full plots) and the contribution of each nutrient to the total score for each food item.

Offals received the highest score under both calculation methods, mostly due to high vitamin B12, vitamin A, and copper content. High-calorie foods such as seeds and nuts scored highly per 100 g, whereas seafood and non-starchy vegetables performed well per 100 kcal. The nutrients contributing to the high scores varied considerably between food items, even within the same food group. For example, the largest contributing nutrients to the top three seeds in the per 100 g rankings were vitamin E for sunflower seed, copper for sesame seed, and selenium for rape and mustard seed. No single nutrient dominated in determining high scores across the FBS items.

When considering food groups rather than items, Other Meat appeared high in the rankings, due to offal being part of this group (Figure 2). Nuts (which consists of only the single FBS item Nuts and products) appeared at the top of the mass rankings, but in the lower half of the energy rankings, due to the relatively high energy content of nuts. Oilcrops saw a similar change between the mass rankings and the energy rankings, for the same reason. Seafood, pulses, and eggs were consistently highly ranked, but with substantial variation between items within the seafood group. Sugar was consistently the lowest ranked. Dairy received relatively low scores and rankings, explained by its high water content per 100 g and its low content of several micronutrients included in the scoring (e.g. iron, vitamin C).

4 | Discussion

The results show an illustrative example of the use of the tool in assessing the relative nutrient density of FBS items. The intention of the study is to provide an accessible means for researchers and stakeholders interested in micronutrient deficiency to better understand the composition of these foods in comparison to nutrient intake requirements. For example, it would be possible to use the tool in combination with dietary intake data to ascertain the foods densest in the nutrients underconsumed by a particular

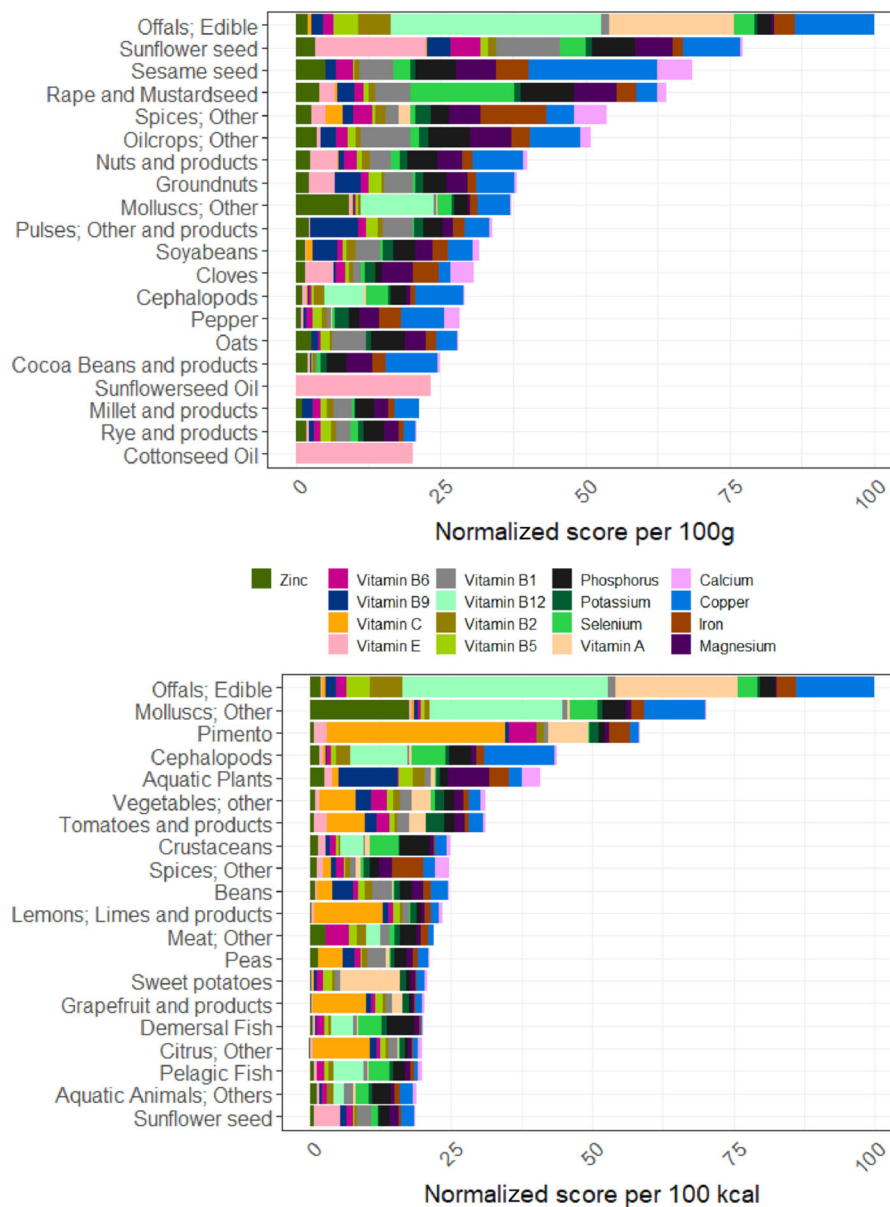


FIGURE 1 | Normalized micronutrient density scores of the top 20 Food Balance Sheet items when calculated on a mass (top) or energy (bottom) basis. Note the top 20 items differ between the two calculation methodologies. Color coding indicates the contribution of each nutrient to the overall item score.

population group. These foods could then be prioritized in interventions to improve nutritional status.

It is also possible to include macronutrients in the ranking. It may not be appropriate to include energy or carbohydrates in any scoring, as these are only limiting in highly food insecure populations. The tool has also been run with the inclusion of protein and indispensable amino acids; the impact on overall rankings was minor and confined largely to the foods low on both the mass and energy ranking lists.

Calculating a combined mass and energy score by averaging the two is possible, or one could give varied weights to the nutrients included. We calculated a combined mass and energy score, which provided a hybrid view between the panels of both

Figures 1 and 2 (Figure S3). Offal, seeds, and some seafood were the highest ranked food items, largely based on their vitamin B12, vitamin A, copper, and/or vitamin E content. The food groups that performed well in Figure 2 remained highly ranked in the combined calculation. We have not attempted any weighting of included nutrients, but this would be a straightforward inclusion and could be based on the extent of inadequate supply or intake in a target population (Ridout 2021).

The data underlying the calculation have several limitations worthy of note. First, it is widely acknowledged that the FBS items provide insufficient detail for many foods to be useful for assessing consumption (M. R. Smith et al. 2016). FBS items focus on produced commodities and often group commodities together rather than enumerate quantities of diverse individual

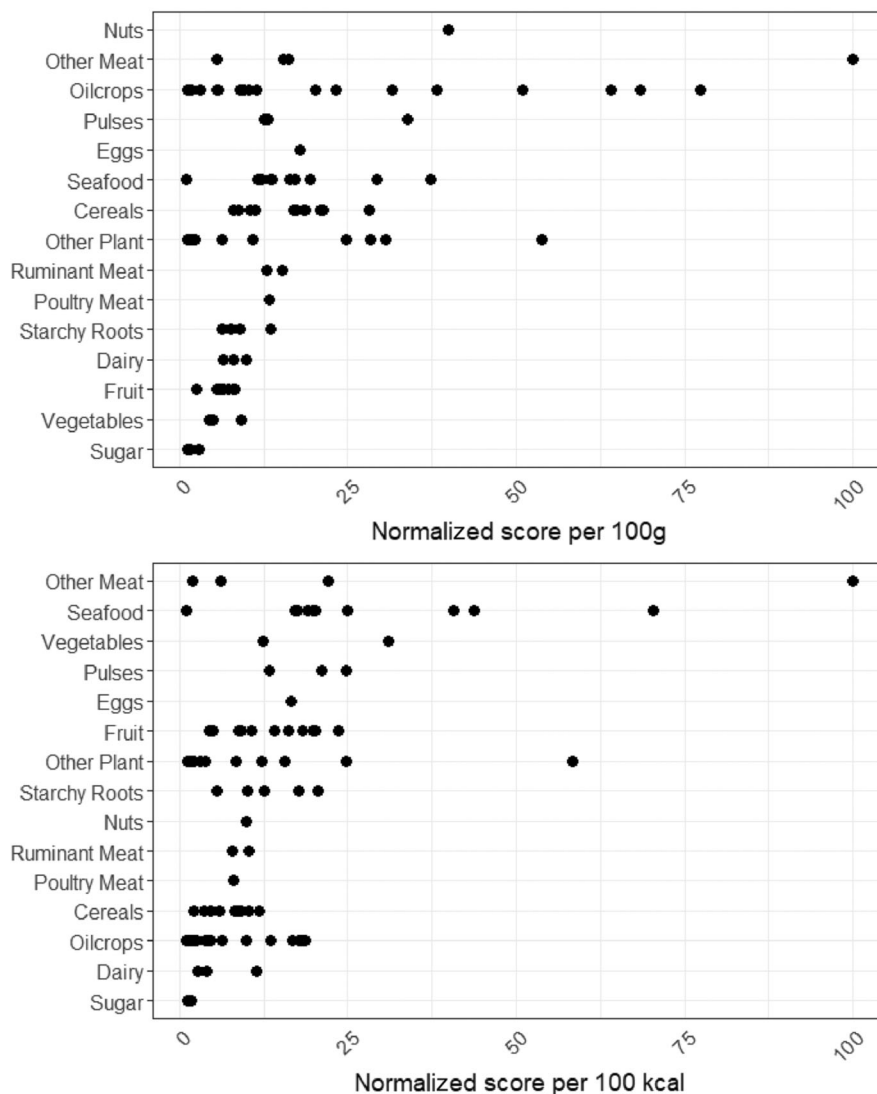


FIGURE 2 | Plot showing normalized micronutrient density scores of all Food Balance Sheet items, grouped by broad food group. Values on a mass basis (top) and an energy basis (bottom) are shown. Groups are ordered from top to bottom by average normalized score across all Food Balance Sheet items in the group.

foods. A key example is the FBS item “Vegetables; other,” which captures foods as different in nutrient composition as cucumbers, pumpkins, and brassicas. Thus, the aggregation of these foods into a single item hides the variation in scores that would be achieved by each food alone. Indeed, other nutrient density metrics have highlighted the value of dark leafy greens as one of the most nutrient dense foods (Beal and Ortenzi 2022), which was not apparent here due to the FBS grouping. The resolution of food items used in nutrient density calculations should match the resolution of the challenge being addressed.

Food composition data also do not capture food as consumed. This tool’s focus on FBS items reflects the composition of foods “as produced,” rather than “as consumed,” which is a limitation. Combinations of foods into meals and diets have a significant impact on nutrient absorption, as does the food source. Nutrient bioavailability is poorly understood for most nutrients (Chungchunlam and Moughan 2023), the exceptions being protein (Adhikari et al. 2022; FAO 2013), and to a lesser

extent iron, zinc, and calcium (Beal et al. 2017; Beal and Ortenzi 2022; Weaver et al. 2024). At present, the DELTA Model integrates true ileal digestibility of protein and indispensable amino acids into its calculations on a food item level, but bioavailability is not captured for any other nutrients in the nutrient density tool. Approximations exist and have been applied elsewhere for adjusting for mineral bioavailability at the food item level (e.g., by Beal and Ortenzi (2022)), but individual nutrient status, the diet, meal, and individual context—for example, the interaction between non-heme iron and vitamin C, or the reduction in calcium absorption with age—are far more determining of mineral absorption than is the case for protein (EFSA 2010; Shlisky et al. 2022). It was therefore decided not to apply any adjustment here, given the low resolution of the FBS food items and the various contexts in which the tool may be applied.

In conclusion, we have leveraged data from an existing food system model to characterize the micronutrient density of FBS items. The tool developed is flexible to allow focus on any number

of nutrients of interest and could be used as a screening tool to identify foods with strong potential for addressing a specific set of nutrient deficiencies.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.