# Healthy and sustainable diets: providing nutrition, not only nutrients

**Thom Huppertz**[1,2*]
[1]Wageningen University & Research, Wageningen, The Netherlands
[2]FrieslandCampina, Amersfoort, The Netherlands

## Introduction

The primary purpose of the food system is abundantly clear: providing healthy diets to a world population within planetary boundaries. However, the routes towards this goal are less clear and heavily debated. Within this context, the replacement of animal-based products with plant-based products is often advocated, but such recommendations are often made on the, rather reductionist, consideration of animal-based products mainly as a protein source, and do not consider the broader context of nutrients and nutrition provided by different food products. As such, a product-for-product replacement based on a single nutrient may lead to further impact in the diet, leading to nutrient deficiencies. Furthermore, it is important to keep in mind that nutrients in food products should not only be considered quantitively (i.e., the concentration of a nutrient) but also qualitatively (i.e., the nutrient being present in the right form to contribute to nutrition). Unfortunately, many approaches that have been applied focus primarily (or even exclusively) on nutrient quantities, and not nutrient quality, which can have notable impact on human nutrition and health.

## Nutrients and nutrition

Although food items are consumed by people for a variety of reasons, their primary importance is that they are a source of nutrients and thus contribute to nutrition. The distinction between nutrients and nutrition is important: nutrition can be defined as the process in which an organism uses food to support its normal growth, development and maintenance of health via ingestion, absorption, assimilation, biosynthesis, catabolism and excretion. Food items are the source of nutrients used for this purpose, but nutrition entails much more than solely the ingestion of nutrients. In other words, nutrients are essential for nutrition, but nutrients alone are not sufficient.

For nutrients to actually contribute to nutrition, and ultimately human health, they need to be absorbed by the body, followed by subsequent utilization. For nutrients to become available for absorption, they need to be liberated from the food matrix, i.e., they need to become bioaccessible (Melse-Boonstra *et al.*, 2020). In the case of minerals, such as calcium or zinc, this means that they should be present in ionised form, i.e., as $Ca^{2+}$ or $Zn^{2+}$. In other forms, i.e., complexed with other ions, these minerals cannot be absorbed. For macronutrients, digestion is typically required prior to absorption (Capuano & Janssen, 2021). Carbohydrates need to be broken down to their constituent monosaccharides, lipids to free fatty acids, and monoglycerides and proteins to their constituent amino acids or di- and tripeptides. Without this, nutrients cannot be absorbed and thus cannot contribute to nutrition, and ultimately health.

## Nutrient bioavailability: calcium as an example

As outlined in the previous section, the ingestion of nutrients alone is not sufficient to provide nutrition, and a key step in this is that they need to be bioavailable. Bioavailability is a crucial parameter for almost all micronutrients, including minerals and vitamins. In some cases, this is also considered in recommended daily intake (RDI) values, i.e., in the case of iron and zinc. For iron, an RDI of 14 mg is recommended for diversified diets, rich in meat fish, poultry, and/or rich in fruit and vegetables, whereas for diets rich in cereals, roots or tubers, with some meat, fish, poultry and/or containing some fruit and vegetables, the RDI is 22 mg (CODEX, 2017). Likewise, for zinc, the RDI is 11 mg for mixed diets, and lacto-ovo vegetarian diets that are not based on unrefined cereal grains or flours with high extraction rate (>90%), but 14 mg for cereal-based diets, with >50% energy intake from cereal grains or legumes and negligible intake of animal protein (CODEX, 2017). In both cases, the

*Correspondence: thom.huppertz@frieslandcampina.com

**Thom Huppertz** holds an MSc from Wageningen University and a PhD from University College Cork. Prof Huppertz's research career includes academic and industrial research in the field of dairy science and technology, with dairy chemistry and physics as a central theme.

His research topics have ranged from biosynthesis of milk constituents to digestion of dairy products in the human body, and from product and process optimisation to the role of dairy products in a healthy sustainable diet and nutrient quality and bioavailability. He currently combines the roles of Professor of Dairy Science and Technology at Wageningen University, Principal Scientist at FrieslandCampina, Visiting Professor at Victoria University of Melbourne, and Editor-in-Chief of the *International Dairy Journal.*

RDI is adjusted based on the main sources of the nutrient and considers, e.g., the higher bioavailability of iron and zinc from animal-based products (Solomons, 1982; Hurrell & Egli, 2010; Platel & Srinivasan, 2016). However, such diet-dependent RDI values are not considered for other micronutrients, despite the fact that differences in bioavailability are clearly apparent.

Calcium, in this respect, forms an interesting example: calcium is an indispensable micronutrient that is required by the body for bone health, teeth and many biochemical processes. Compared to most other micronutrients, calcium requirements are comparatively high, with RDI values of approximately 1 g per day for adults (CODEX, 2017; EFSA, 2017). Meeting these requirements thus requires food products that are comparatively rich in calcium and that allow them to be met without excessive energy intake. Some examples of food products including their calcium content, also expressed on a caloric basis, as well as their Ca per serving, are shown in Table 1. From this, it is clear that approx. 3 servings of milk per day are required to achieve the aforementioned RDI, whereas many more servings of other products are needed. For broccoli, this would also entail a notable increase in caloric intake. For spinach, Ca/energy ratio is favorable, but the low concentrations would require high intake.

Table 1: Ca content of selected food products (data from the Dutch Food Composition Database (NEVO) published by the National Institute for Public Health and the Environment, RIVM (https://www.rivm.nl/en/dutch-food-composition-database/access-nevo-data/nevo-online).

| Food item | Ca (mg/100 g) | Energy (kcal/100 g) | Ca/energy (mg/ kcal) | Serving size (g) | Ca/serving (mg) |
|---|---|---|---|---|---|
| Milk | 124 | 61 | 2.0 | 250 | 310 |
| Cheese | 740 | 379 | 2.0 | 20 | 148 |
| Broccoli | 38 | 27 | 1.4 | 45 | 17.1 |
| Spinach | 105 | 26 | 4.0 | 80 | 84 |

In many Western diets, dairy products are the main source of dietary calcium. For example, in the Netherlands, close to 60% of all dietary calcium is supplied via dairy products. However, in other countries where dairy consumption is notably lower, other product categories become more dominant sources of calcium. For example, in many countries in South-East Asia and Sub-Saharan Africa, plant-based products are the main dietary source of calcium (DELTA model: https://sustainable-nutritioninitiative.com/sustainable-nutrition-initiative/; Smith *et al.*, 2021). When considering products as a source of calcium, not only calcium content, but also bioavailability should be considered. Table 2 highlights bioavailability of calcium from the same products as are shown in Table 1. From this, it is clear that (1) bioavailability is never 100%, and only exceeds 50% for broccoli, and (2) there are wide variations between products. Some products (e.g., spinach (Table 2), but also rhubarb, beans, seeds, grains) have notably lower bioavailability of calcium, which can be related to the presence of oxalate or phytate in such products (Weaver *et al.*, 1999). These compounds bind calcium strongly and impair its absorption in the body. From this perspective, it is important to recognise that RDI values for calcium are based on calcium balance studies conducted mainly on Western diets (FAO, 2002), which, as outlined earlier, are rich in dairy. For non-Western diets, which often derive a much higher proportion of calcium from non-dairy sources, RDI values for calcium may thus need to be elevated further. Likewise, for vegan diets, higher RDI values for calcium also appear warranted to compensate for lower bioavailability, as is also done by CODEX (2017) for zinc and iron.

Table 2: Ca content of selected food products (data from the Dutch Food Composition Database (NEVO) published by the National Institute for Public Health and the Environment, RIVM (https://www.rivm.nl/en/dutch-food-composition-database/access-nevo-data/nevo-online).

| Food item | Ca (mg/100 g)[1] | Estimated absorption (%)[2] | Absorbed Ca (mg/100 g) | Serving size (g)[1] | Absorbed Ca/ serving (mg) |
|---|---|---|---|---|---|
| Milk | 124 | 32 | 40 | 250 | 99 |
| Cheese | 740 | 32 | 237 | 20 | 47 |
| Broccoli | 38 | 61 | 23 | 45 | 10 |
| Spinach | 105 | 5 | 5 | 80 | 4 |

[1]Data from the Dutch Food Composition Database (NEVO) published by the National Institute for Public Health and the Environment, RIVM (https://www.rivm.nl/en/dutch-food-composition-database/access-nevo-data/nevo-online).
[2]Data from Weaver *et al.* (1999)

## Nutrient quality: protein quality as an example

Although protein is often considered to be an indispensable nutrient, it is really its building blocks, i.e., the amino acids, that are the indispensable nutrients. More specifically 9 out of the 20 amino acids (Val, Leu, Ile, Lys, Phe, Trp, Lys, Met and Thr) cannot be synthesised by the human body and thus need to be provided via food. The other 11 amino acids can be synthesised by the human body and are thus not deemed indispensable. However, their synthesis does require sufficient dietary nitrogen, for which protein is also the only dietary source. Therefore, from a dietary perspective, proteins should be considered as both a source of indispensable amino acids (IAA) and nitrogen (FAO, 2013). Of course, for both to be utilised efficiently, they need to be absorbed. The ability of a protein to supply sufficient levels of IAA and nitrogen in absorbable form is typically referred to as protein quality.

Protein quality has been measured in different ways over the years. From the early 1990s, the protein digestibility-corrected amino acid score (PDCAAS) became the global standard, based on recommendations by FAO. The method has, however, to a large extent been superseded by the digestible indispensable amino acid score (DIAAS). The main advantages of DIAAS over PDCAAS are that it is based on ileal rather than fecal digestibility and that it measures amino acids individually, rather than measuring total nitrogen and assuming every amino acid to have the same digestibility factor, as is done in PDCAAS (FAO, 2013; Moughan & Wolfe, 2019). Obtaining a DIAAS score for a protein source requires the following information (FAO, 2013):

1. Amino acid composition of the protein (expressed in mg/g protein)
2. Standardised ileal digestibility (SID) of each IAA
3. A reference amino acid pattern for the IAA (expressed in mg/g protein)

From (1) and (2) above, the amount of digestible amino acid can be calculated for each IAA and by comparison to the reference pattern from 3), and a scoring pattern for each IAA can be calculated. In DIAAS, the most limiting IAA (i.e., the lowest score compared to the reference pattern) is considered the value for protein quality, and expressed as either a ratio or a percentage of the reference pattern. In other words, a DIAAS score of 1 (or 100%) indicates that all IAA are supplied in digestible form at the required level, whereas a score <1 (or <100%) indicates that at least one IAA is not provided in digestible form at the required level via the protein. This can be because the protein does not contain sufficient amounts of this IAA, its digestibility is low, or a combination of these. DIAAS values >1 (or >100%) are also possible. In this case, all IAAs are present at digestible levels above the requirements. This should, however, not be taken as an indication that less of a protein with a DIAAS score of 1.2 needs to be consumed than with a score of 1.0, as in the former case, nitrogen levels rather than specific IAA can become limiting.

DIAAS scores have been determined for a wide range of protein sources. An overview of some reported scores is provided in Table 3. In addition to the DIAAS score, this table also includes the first limiting IAA and the SID of that IAA. From Table 3, it is clear that there is a wide variety in DIAAS scores for different protein sources. In general, animal-derived sources score rather high on DIAAS, with scores typically exceeding 90%. For plant-based protein sources, much more variation is observed. While the soy protein score is relatively high, other sources, such as e.g., rice, wheat and sorghum score much lower.

Consideration of protein quality, however, should not be limited to a single score for a protein source based on a single IAA, as this ignores another key aspect, i.e., the complementarity of different protein sources. Many plant proteins, for example, lack sufficient levels of digestible Lys, whereas many animal protein sources contain a notable excess of digestible Lys (Moughan, 2021). Consumption of these sources together in a meal can thus lead to complementarity, where one protein source can compensate for deficiencies in another protein source. A key example of this is, for example, in a typical cereal-based breakfast with milk or yoghurt, where the excess Lys from the latter can compensate for deficiencies in the former, thus highlighting a strong synergy between plant-based and animal-based protein sources. It is crucial, however, that such complementarity is considered on a meal basis, and not a dietary basis.

## Conclusions and future perspectives

Our global food system will undoubtedly be changing in the future, but its primary aim of providing healthy diets for the world population will certainly not change. These healthy diets include providing nutrients in digestible and bioavailable form to ensure that they can contribute to nutrition, and ultimately human health. Such aspects, however, appear to be readily overlooked in many, sometimes polarising, discussions on the topic of healthy and sustainable diets, with the risk of the quality of diets becoming a deprioritised factor. Balanced considerations of configurations of potential future food systems including not only the provision of nutrients, but also nutrition, is therefore essential to safeguard human health for now and generations to come.

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Table 3: DIAAS scores from selected protein sources, including the first limiting amino acid (FLAA) and the standardized ileal digestibility (SID) of the FLAA

| Protein source | DIAAS (%) | FLAA | SID of FLAA (%) | Reference |
|---|---|---|---|---|
| Skim milk powder | 127 | Met+Cys | 94 | Mathai *et al.* (2017) |
| Egg | 122 | Met+Cys | 75 | Heo (2012) |
| Beef (steak, pan-fried) | 98 | Val | 99 | Hodgkinson *et al.* (2018) |
| Pea protein concentrate | 73 | Met+Cys | 78 | Matthai et al. (2017 |
| Rice | 60 | Lys | 92 | Cervantes-Pahm *et al.* (2014) |
| Wheat | 43 | Lys | 73 | Cervantes-Pahm *et al.* (2014) |
| Sorghum | 29 | Lys | 69 | Cervantes-Pahm *et al.* (2014) |