

NUTRI FUSION™

Nutrient Bioavailability - Getting the Most Out of Food

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When we consume a food or drink, the nutrients contained are released from the matrix, absorbed into the bloodstream and transported to their respective target tissues. However, not all nutrients can be utilized to the same extent. In other words, they differ in their bioavailability. Understanding nutrient bioavailability helps optimize diets and set appropriate nutrient recommendations.

Defining nutrient bioavailability

Several definitions exist for nutrient bioavailability, but broadly it refers to the proportion of a nutrient that is absorbed from the diet and used for normal body functions.^{1,2} The following components describe the different steps of the metabolic pathway where changes in nutrient bioavailability may occur¹:

- release of the nutrient from the physicochemical dietary matrix
- effects of digestive enzymes in the intestine
- binding and uptake by the intestinal mucosa
- transfer across the gut wall (passing through the cells, in-between them or both) to the blood or lymphatic circulation
- systemic distribution
- systemic deposition (stores)
- metabolic and functional use
- excretion (via urine or feces)

As is evident from this list, the bioavailability of a nutrient is governed by external and internal factors. External factors include the food matrix and the chemical form of the nutrient in question, whereas gender, age, nutrient status and life stage (e.g. pregnancy) are among the internal factors. Because aspects such as nutrient status also determine whether and how much of a nutrient is actually used, stored or excreted, some definitions of bioavailability restrict themselves to the fraction of a nutrient that is absorbed.³

The bioavailability of macronutrients – carbohydrates, proteins, fats – is usually very high at more than 90% of the amount ingested. On the other hand, micronutrients, i.e. vitamins and minerals, and bioactive phytochemicals (e.g. flavonoids, carotenoids) can vary widely in the extent they are absorbed and utilized. Therefore, the following sections will use micronutrients and phytochemicals as examples to illustrate the different stages at which nutrient bioavailability can be influenced.

Effects of food matrix and chemical form of nutrients

The first step in making a nutrient bioavailable is to liberate it from the food matrix and turn it into a chemical form that can bind to and enter the gut cells or pass between them. Collectively this is referred to as bioaccessibility.⁴ Nutrients are rendered bio accessible by the processes of chewing (mastication) and initial enzymatic digestion of the food in the mouth, mixing with acid and further enzymes in the gastric juice upon swallowing, and finally release into the small intestine, the major site of nutrient absorption. Here, yet more enzymes, supplied by the pancreatic juice, continue breaking down the food matrix.

In addition to the bodily means of mastication and enzyme action, the digestibility of food matrices, especially of plant foods, is aided by cooking or pureeing the food. For example, whereas raw carrots and spinach are good sources of dietary fiber, cooking them allows the human body to also extract a much larger fraction of the carotenoids contained.⁵

Minerals and other nutrients exist in different chemical forms in the food and this can influence their bioavailability. A classic example is iron. In general we talk about two types of dietary iron; haem and non-haem iron. The former is only found in meat, fish and poultry, whereas the latter occurs in foods of plant and animal origin. Haem iron mainly stems from the hemoglobin and myoglobin molecules responsible for oxygen transport and storage in the blood and muscles, respectively. Once released from the food matrix, the haem molecule acts like a protective ring around the central iron atom. Thus, it shields the iron from interaction with other food components, keeps it soluble in the intestine, and is absorbed intact through a specific transport system on the surface of the gut cells.⁶ In contrast, non-haem iron is poorly soluble under intestinal conditions and easily affected by other components of the diet.² Therefore only a small fraction is taken up by the cells.

Sometimes vitamins and minerals are added to foods to increase their nutritional value - a process called fortification. In the case of the B vitamin folic acid, which is often added to breakfast cereals, flour and certain spreads, this added folic acid usually is more bioavailable than that naturally present in the food, commonly referred to as dietary folate. Studies reported 20-70% lower bioavailability of dietary folate (from fruits, vegetables or liver) vs. synthetic folic acid.⁷ This does not mean though that one should only consume foods fortified with folic acid, but rather that natural dietary sources such as green leafy vegetables can be complemented with foods fortified with this vitamin to ensure that individual requirements are met.

Enhancers of nutrient bioavailability

Nutrients can interact with one another or with other dietary components at the site of absorption, resulting in either a change in bioavailability or – if enhancers and inhibitors cancel each other out – a nil effect. Enhancers can act in different ways such as keeping a nutrient soluble or protecting it from interaction with inhibitors. For example, since carotenoids are fat-soluble, adding small quantities of fat or oil to the meal (3-5 g per meal) improves their bioavailability.⁹ Similarly, meat, fish and poultry, while containing highly bioavailable iron themselves, are also known to enhance the absorption of iron from all foods. Although this ‘meat factor’ has yet to be identified, an influence of the muscle protein has been suggested.¹⁰

Vitamin C is also a strong ‘helper’, being able to increase iron absorption by two or three times.¹¹ This means, for example, having a glass of orange juice with a bowl of breakfast cereal helps the body use more of the iron in the cereal.

Impact of inhibitors on nutrient bioavailability

Inhibitors may reduce nutrient bioavailability by: i) binding the nutrient in question in a form that is not recognized by the uptake systems on the surface of intestinal cells, ii) rendering the nutrient insoluble and thus unavailable for absorption, or iii) competing for the same uptake system. Phytic acid is highly abundant in certain plant foods (e.g. pulses, whole-grain cereals, seeds, nuts) and strongly binds minerals such as calcium, iron and zinc in soluble or insoluble complexes that are unavailable for absorption.¹² Ways to reduce the phytic acid content of foods include fermentation (e.g. extensive leavening of whole meal bread dough) or the soaking and germination of pulses.¹³

An example of competition for the same uptake system is the interaction between calcium and non-haem iron. Both minerals bind to a transporter on the surface of intestinal absorptive cells, but whereas non-haem iron enters the cells this way, calcium basically stays in the doorway and hinders further entry of the iron. This effect is mainly relevant when calcium and/or iron supplements are used outside the meal setting.¹⁴ Therefore; the best advice is to use those supplements at different times of day so as to avoid this interference.

The inhibitory effect of food constituents can also be used advantageously, as is done in the case of phytosterols. These natural compounds are extracted from certain plant foods and added in higher doses (about 2 g per portion) to various other foods (for example enriched spreads, fermented milk drinks) in order to lower the absorption of cholesterol, be it from dietary sources or produced in the human body.¹⁵

Host factors

Internal or host-related factors can be subdivided into gastrointestinal and systemic factors. The role of gastrointestinal factors is illustrated by the absorptive pathway of vitamin B₁₂. This vitamin requires gastric acid to be released from the food matrix and then it undergoes a sequence of binding to R protein, release from R protein, binding to the protein “intrinsic factor” (IF) and finally absorption of the intact IF-vitamin B₁₂ complex in the lower intestine.¹⁶ R protein, IF and gastric acid are all produced in the gastric mucosa, and functional decline of this mucosa – as may occur in the elderly and with certain conditions – can compromise their production and thus vitamin B₁₂ bioavailability.

Systemic factors include deficiency of a certain nutrient or changes in physiologic state, e.g. pregnancy. In both cases, the body may respond by increasing the respective nutrient absorptive pathway or utilization to meet the increased demand.¹⁴ Calcium and zinc are among the nutrients regulated in this way. On the other hand, some inflammatory conditions or infections may reduce the absorptive capacity of the gut. For example, the absorption of iron is down-regulated in people suffering from acute infections such as the common cold.¹⁷

Impact on nutrient recommendations

For several nutrients – primarily calcium, magnesium, iron, zinc, folate and vitamin A – knowledge of their bioavailability is needed to translate physiological requirements into actual dietary requirements.¹⁴ The magnitude of adjustments varies by nutrient, habitual diet and a number of host-related factors, most of which are difficult to assess. Considering all these influences, it is not surprising that nutrient-based dietary recommendations differ between countries and institutions, but efforts are being undertaken by the EURRECA Network of Excellence to standardize assessment methodologies across Europe.¹⁸

References

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