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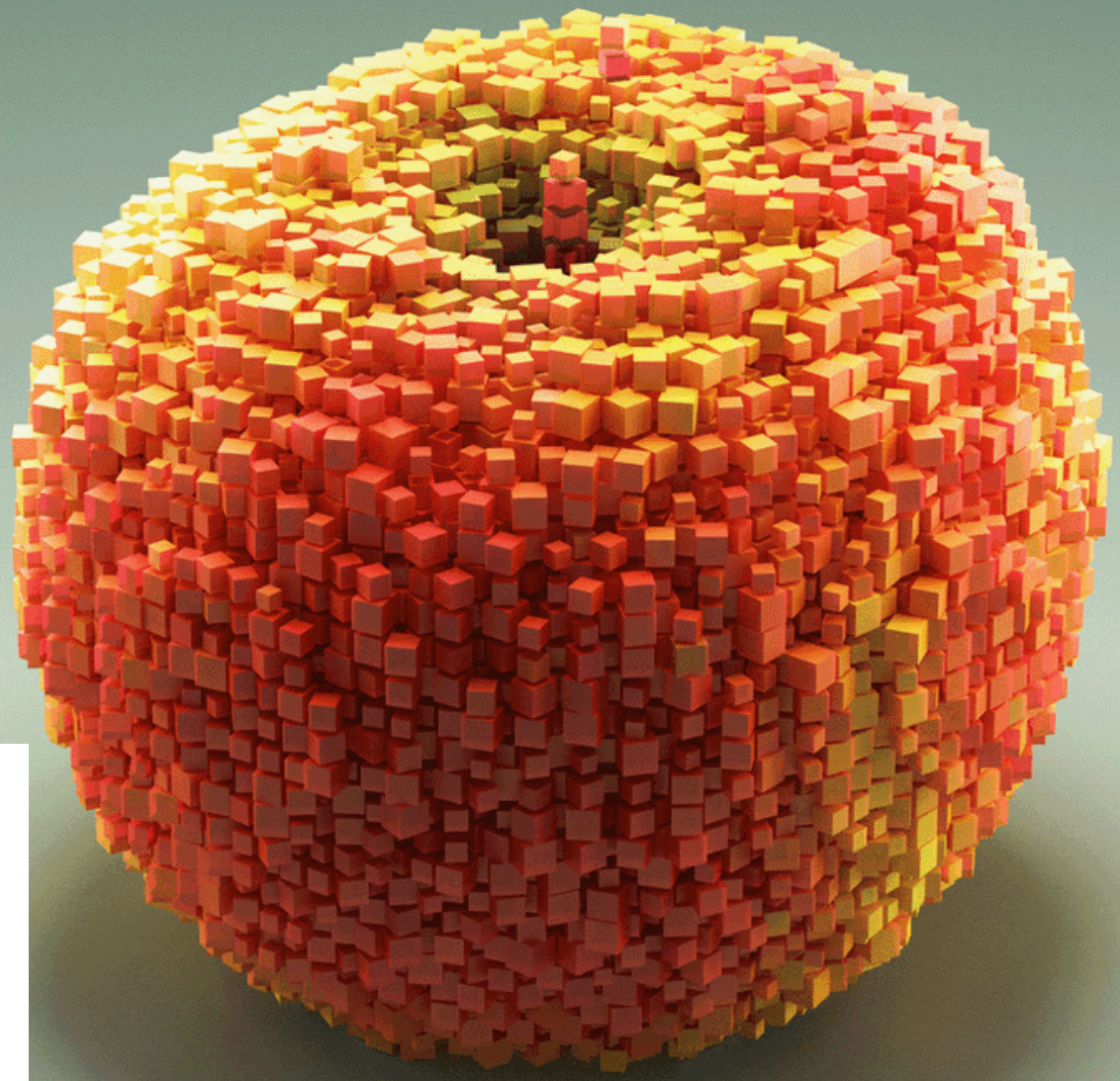

The application of AI in nutrient bioavailability and precision nutrition

Introduction

With nutrient bioavailability so crucial to product efficacy and health claims across the healthy foods and supplements sectors, we look to what artificial intelligence (AI) is bringing to this area of new product development – along with its integration into precision nutrition.

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AI-driven acceleration

While AI tools have been used in the nutrition space for more than a decade, and some consider them over-hyped as a product development aid, most companies, be they suppliers or product formulators/marketers, are utilising AI in one way or another, from precision nutrition modelling to ingredient discovery and development.

Those already heavily invested in AI-led nutrition operations are predictably evangelistic about what AI can do, while others are more sceptical, often citing the relative scarcity of clinical data for AI applications and broader concerns about how accurate and trustworthy some AI-generated material and insights are.

"AI is very good at reading lots and lots and lots of text," said Akash Shah, co-founder of the Bayer-owned, consumer-facing personalised nutrition firm Care/of, which is about to launch a proprietary IngredientAI platform.[1] "It's also very good at writing lots and lots and lots of text, but what it's not good at is judgement."

IngredientAI will have an in-built fact-check system to mandate references for any statement it makes. "You want to make sure that there's essentially quality assurance in addition to the human in the loop, so that people aren't blindly making decisions," said Shah.

Read more Fast-tracking 'transformative' ingredient discovery: How AI is changing new product development

Despite such limitations – and there are others – it is hard to deny AI's promise in multiple areas.

Its vast potential is already being converted into real gains in bioavailability, nutrient discovery, and in areas like clinical nutrition[2-4] and malnutrition,[5] where the need is perhaps greatest – not to mention among the general population, where nutrient deficiencies including iron, vitamin A, zinc, folic acid, vitamin D, and iodine are shockingly common.

An 'acceleration of discovery'

"[AI] looks at many more interactions from much more data than a human could do," Tony Van Campen, co-founder of Belgian AI-driven nutrition startup Biomdrin, told *Nutrition Business Journal (NBJ)*, while agreeing that "it still takes the human to make that into something that's practical".[6]

Biomdrin's AI tool crunches research and other data around gene and protein

expression for something like 70,000 ingredients, before suggesting formulations that humans then scrutinise for potential development.

Van Campen said the real benefit was how fast AI was capable of "weeding out the bad from the good".

"I can have an idea today, testing tomorrow, and know if I'm on the right path," he said. "That's an acceleration of discovery that I think will be very beneficial for the industry."

Nora Khaldi, PhD, the founder and CEO of Irish, AI-driven, peptide-focused startup Nuritas, echoed these accelerated discovery sentiments, saying: "We can't use the traditional ways of finding ingredients any more. They're too long, too expensive, and actually [have] very little chance of creating something, even when you spend the money and time."[7]

The 10-year-old company, which had its first AI-discovered peptides appear in a clinical trial in 2017, presently counts the likes of food and supplement majors BASF, Nestlé, Sumitomo, Pharmavite, Metagenics, and Mars as clients.

Mars itself has partnered with the AI life science company Process Integration & Predictive Analytics (PIPA) to discover

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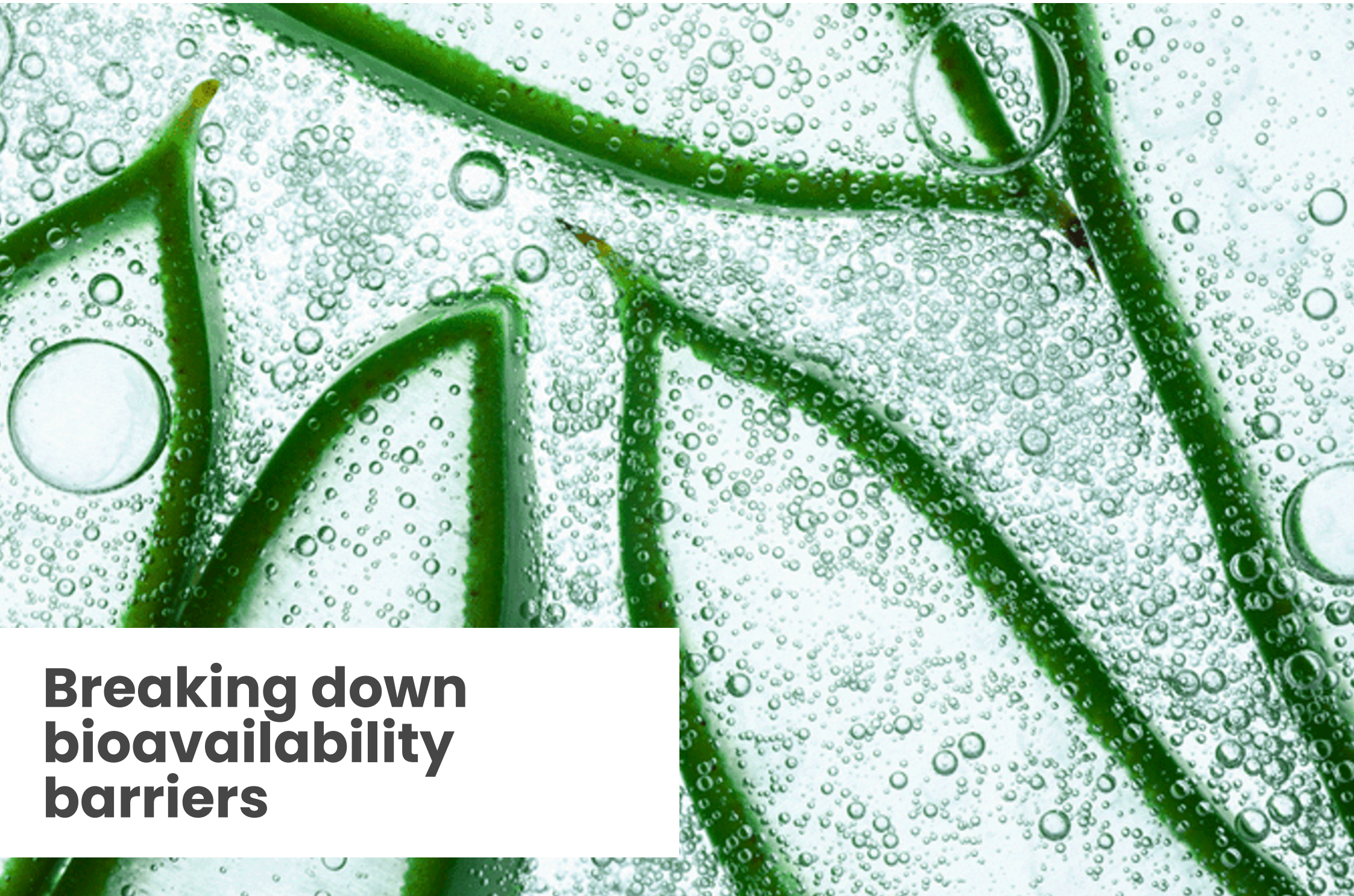
> Tony Van Campen, co-founder, Biomdrin

botanical ingredients for foods and supplements for particular health endpoints.[8]

PIPA's LEAP AI platform pools data from over 20 million research papers and 60 knowledge bases and semantic networks, and cross-references against some 16,000 health conditions.

California-based Brightseed Bioactives[9] is doing similar things by using its Forager AI platform to locate potent bioactives in plant and other sources and is working with the likes of Manitoba Harvest,[10] Danone, and ADM on product development.[11]



Breaking down bioavailability barriers

AI is helping nutrition companies challenge bioavailability barriers that can compromise product efficacy due to nutrient integrity issues or nutrient interactions – and leave consumers questioning health claims and product efficacy in potentially sector-damaging ways.

For the purposes of this article, boosting bioavailability means, according to one fairly popular definition, "increasing the fraction of an ingested nutrient that becomes available for use and storage in the body".[12] But that rather elegant definition can be further complicated by whether those particular sites in the body the nutrients are intended for – the organs, tissues, muscles – actually receive them in sufficient quantity to deliver health benefits.[13] In this sense, absorption is very different to bioavailability.

The fact that AI is very good at reading lots and lots of text and processing other massive chunks of raw data is helping unlock some of this complexity. That means better understanding of the intricate relationships between food/supplement composition, processing methods, and drug-nutrient interactions, as well as individual health and physiological factors like age, gender, genetics, and more.

Even sensory elements like taste become

Health at home and biomonitoring

Step back and the broader AI/nutrition landscape includes the rise of precision nutrition coupled with, as a recent McKinsey global wellness market report called it,[14] "health at home" and "biomonitoring". These developments mean more people are mapping their nutrient profiles and deficiencies[15] – and seeking out evidence-driven nutrition products that can aid them in their quest to optimise their health.

Products that can offer verified nutrient bioavailability and performance enhancement – at least if it is trackable in some population cohorts if not individuals – can tap potentially lucrative markets. The same McKinsey report (which valued the global wellness market at $1.8 trillion) found that about one in five US and UK citizens prefers "personalised products and services". In China, the figure was more like 30%.

The report also found that healthy food/supplement shoppers were more interested in "clinically proven ingredients", cited by half of US and UK respondents as their number one purchasing influencer, rising above "clean and natural" ingredients from the previous year's survey. "This trend is most pronounced in categories such as over-the-counter medications and vitamins and supplements," the report stated.

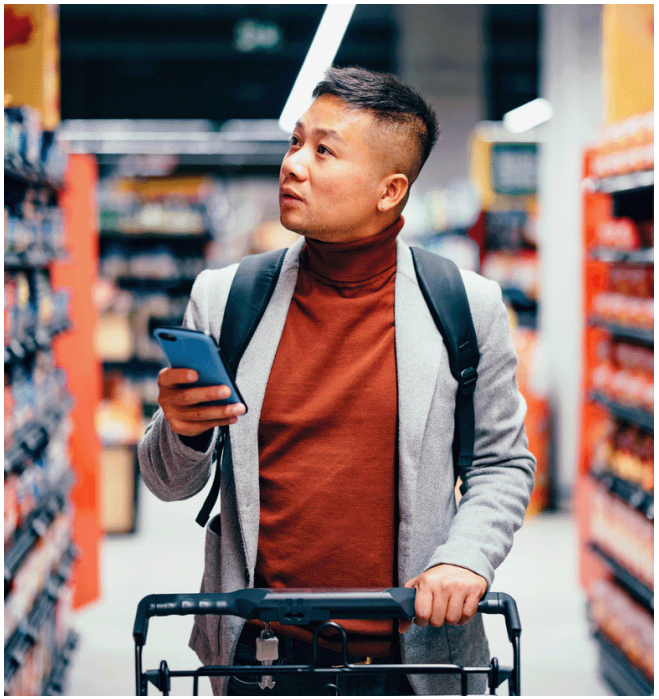
part of the equation – especially when it comes to healthy and fortified foods, where taste is so important to a product's overall appeal and chances of success.

An "electric tongue" is one example where AI is showing promising taste-driven results that can inform the mix of nutrients and their bioavailability in new product development.[16]

Patent activity reveals bioavailability boosting efforts

Consumer demand is clearly strong for products that can deliver big on bioavailability, and producers and research institutions are responding. This is reflected by the spike in volume of patent applications for micronutrient-fortified foods and drinks in recent years.

A Mintel Patent Insights report focused on vitamin and mineral fortification from September 2023 found 800 to 1,000 patents lodged globally each year between 2020 and 2022 for iron-fortified foods/drinks



alone. Many of these were seeking to address the "major public health concern" of anaemia, a condition the World Health Organization estimates 40% of children worldwide suffer from, as well as high numbers of women.[17]

One product example was from Japanese probiotic leader Yakult, which has a patent pending for iron-fortified juice products aimed at women.[18]

Calcium was the next best-represented fortification nutrient, with around 600 patents per year over the same 2020-2022 period, while vitamin B12 and zinc each recorded about 200 patents per year.

Patents included a method to improve calcium stability in fortified dairy alternatives;[19] a method to increase the vitamin B12 content in fermented foods;[20] and a method to improve the amount of zinc available in tea products.[21]

Key health areas were immune function, bone health, and energy. Between 2013 and 2023, China was the source of about a quarter of these patents, followed by the US (9%), South Korea (9%), Japan (7%), and Germany (4%).

Although not always explicit in these patent applications, the use of AI tools is rising in their composition and delivery.

Personalised bioavailability

AI tools analyse vast datasets of food science and nutrition research, nutrition product information, food/supplement processing, storage techniques and methodologies, health and wellness trends, and more to provide insights across ever-expanding sub-cohorts of individuals based on specific dietary choices, gut microbiome composition, and genetic variations.

Imagine personalised/precision nutrition recommendations that can account for an individual's unique absorption potential across a range of nutrients and delivery platforms. This line of questioning has been pursued in some studies that have demonstrated the massive differences in individual nutrient processing in the gut, the bloodstream, and elsewhere in the body.[22]

AI has predicted metabolic responses to food and nutrient intakes among a large number of individuals.[23] An increasingly packed field of startups are utilising this

Read more How closing the ethnicity data gap could save lives

kind of predictive power with enough promising results to keep expanding the customer base and keep the space evolving as AI itself evolves at seemingly ever-accelerating speeds.

Companies like Inside Tracker, Nourished, Prevess, ZOE, Bioniq, Nestlé-owned Persona Nutrition, and Baze are but a few of the precision nutrition players offering the essential promise of bespoke nutrient blends that can push the bioavailability boat out via methods such as blood tests, diet surveys, dose testing, and metabolism modelling.

These personalised nutrition pioneers are increasingly supported by ingredient giants like Dutch-Swiss giant DSM-firmenich, which invested $100m in 2021 in consumer-facing AI-driven health and wellness scale-up Hologram Sciences.

Moving the microbial needle of understanding

DSM-firmenich also launched AI4B.io at the beginning of 2021, an AI-driven collaboration with Delft University of Technology in the Netherlands, to develop bioactives such as probiotic strains.

"AI has already proven to be useful for process optimisation for fermentations, enzyme discovery, and also for dairy

cultures development," said AI4B.io's scientific team.

"Tracking and developing a detailed understanding of microbial behaviour is very complex. When it comes to mixtures of bacteria, like in dairy culture products, it becomes even more difficult."

AI is earning its chops by attempting to make sense of such complexity – and offering solutions that may be beyond human intelligence.

"We can treat our system as a so-called 'black box': certain inputs will lead to certain outputs but how exactly they are related is not always known... AI algorithms can be used to suggest the best input conditions to reach the desired outputs," they added.

AI4B.io was also benefiting from being part of a broader Dutch research initiative, the Innovation Center for Artificial Intelligence (ICAI), and having access to elite athletes' nutrition performance data via a professional cycling outfit.

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AI: Good to have, or must-have?

Professor Giulio Maria Pasinetti, from the Icahn School of Medicine at Mount Sinai in New York, sees a cumulative effect of the data gathered by these companies, research institutions, and government agencies, and others.

It is quickly leading to, said Pasinetti, "a deeper understanding of the diet-gut microbiome interrelationship and attempt to include large nutrigenomics and metabolomics data into personalised healthcare".

One 2022 study used AI to build diets that successfully reduced postprandial glucose responses.[24]

Last year, researchers at the University of California Davis and Goce Delcev University in North Macedonia used AI to better predict individual responses to various nutritional interventions.[25]

Pasinetti said this kind of work was revealing the potential for AI to move beyond "contributing factors to the capability of producing interventional solutions".

Another 2022 study found that AI delivered better clinical outcomes than human recommendations for people seeking body mass index (BMI) reduction.

"As people increasingly rely on applications and other electronic platforms to track and manage their health, the automated nature of AI becomes essential in actively monitoring diet outcomes and updating interventions as treatment progresses," Pasinetti said.

Don't stab the lab in the back

As noted above, none of this is to suggest that, because AI tools are on hand, all the mysteries of nutrient behaviour in formulations and bodies are suddenly apparent.

"We built in the lab digestive systems where we followed the molecule through the digestive system and we did thousands, millions of those experiments to just build a predictor in the bioavailability space," said Nuritas's Khaldi. "Forget efficacy – efficacy is a whole different world."[26]

Like any tool, if it is ill-purposed, it won't deliver. "You have to go into the lab and produce it, and it's costly and it takes time. But once you get there, you can create ingredients that are transformative," Khaldi added.

For Van Campen at Biomdrin, the litmus test always comes in the lab, not in the computer – via clinical trials, no matter how promising an AI-driven proposition might sound.

"Let's iron out those mistakes and come to a point that we are 99% sure that what comes out makes sense and will run successfully into clinical trial," he told *NBJ*.[27] "And that's the only way we want to take products to market.

"When we formulate products, we put them through clinical trials."

Some other (AI)nnovation zones

From predicting nutrient intake to creating smart packaging, there are myriad ways in which AI is helping to drive innovation in the sector.

Leveraging the microbiome

AI is helping speed up the huge task of microbiome mapping and understanding how specific bacterial communities influence nutrient uptake.[28] The research is filtering through to prebiotics, probiotics, and postbiotic selection.

Other biomes, like the skin microbiome,[29] are also benefiting from AI.

A Mintel Patent Insights report from July 2023 on the potential of probiotics beyond gut health shows how probiotic development – much of it concerned with bioavailability – is progressing at a furious pace, with 1,201 granted or pending patents in 2022; 1,269 in 2021; and 1,164 patents in 2020. (This excludes patents files exclusively in China, of which there were over 2,500 in 2022.)

Gut health (65%), general health (11%), immune function (7%), and liver health (4%) were the most commonly explored health areas in patents between 2013 and 2023.

Some of the patent research work highlights the link between the consumption of certain probiotic strains and the bioavailability/absorption of other nutrients[30] like calcium, proteins, or iron,[31] as well as the production in the gut of nutrients like vitamin B12 and folic acid.

The potential for AI tools to assist with this kind of research is vast.

Predicting nutrient interactions

AI algorithms are doing a lot of legwork in the tricky business of predicting how different nutrients interact within a food or supplement and identifying synergistic or antagonistic effects on absorption. This allows for informed formulation strategies that maximise nutrient uptake, and can also be applied to nutrient-drug interactions.[32]

Tailored packaging and storage solutions

AI algorithms can be used to predict how packaging materials and storage conditions impact nutrient stability and degradation. Imagine smart packaging that monitors and adjusts temperature or humidity to extend shelf life and safeguard nutrient potency.[33]

Food fraud and adulteration detection

AI-powered image recognition and spectroscopy techniques can rapidly detect adulteration in food and supplements, ensuring the authenticity and quality of nutrient sources. They can even use media reports to help.[34]

Sustainable and ethical sourcing

AI helps identify underutilised food sources rich in specific nutrients, promoting sustainable practices and dietary diversity. Think forgotten legumes packed with protein or bio-fortified crops bred for enhanced micronutrient content.[35]

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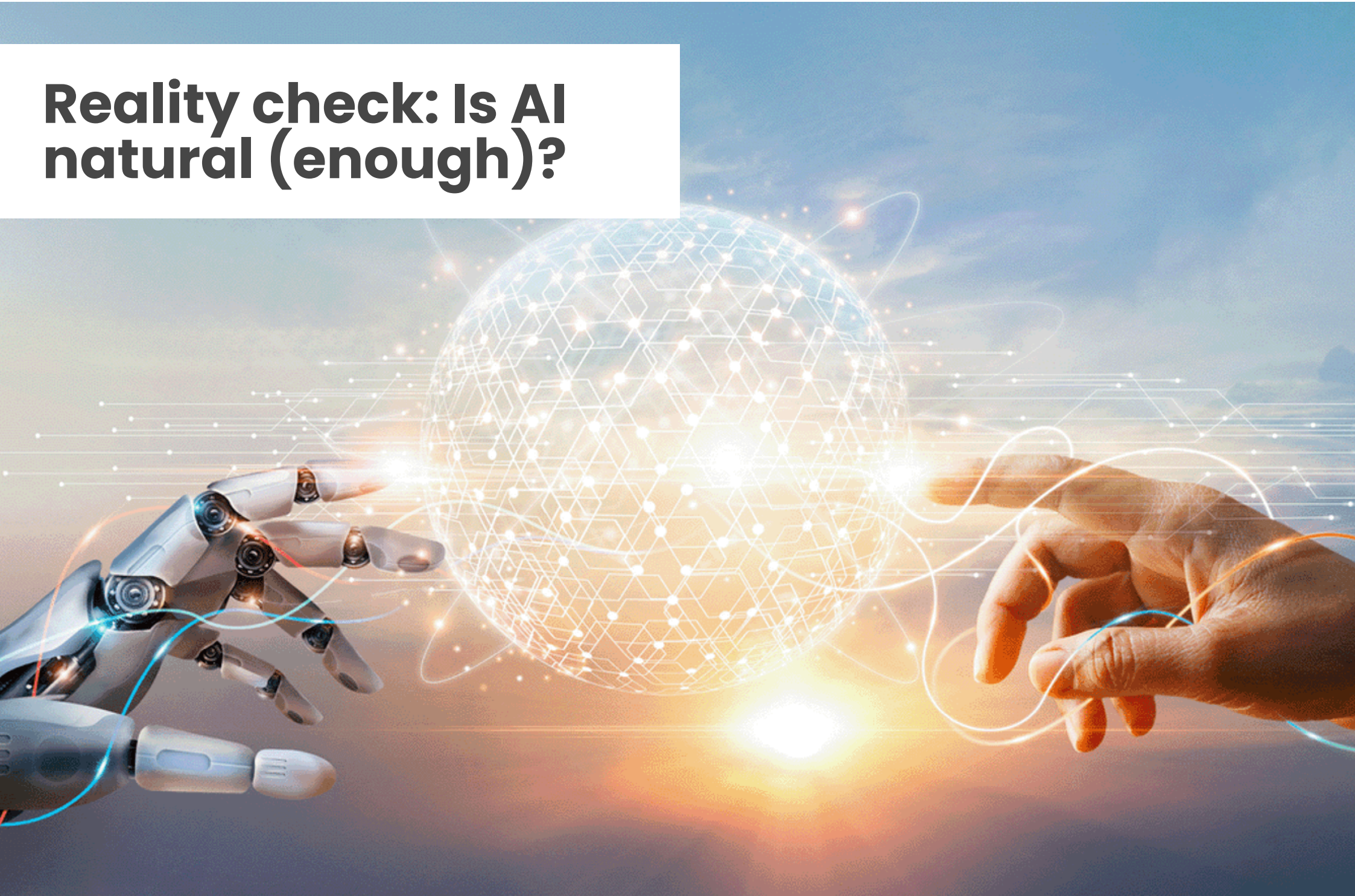
Reality check: Is AI natural (enough)?



Those opposed to the use of AI in the food supply often set up a nature technology dichotomy, illustrated by one health and wellness executive who wrote on LinkedIn: "Preserving natural integrity and sustainability should be our priority, not artificial interventions in food production."[36]

But this assumes "natural integrity" can be preserved when centuries of crop manipulation – through the likes of selective breeding, crop grafting, and genetic modification – suggests that this concept exists more as an ideal than anything reflective of the current food supply that is straining to feed almost eight billion people every day.

AI might be considered an "artificial intervention" but it doesn't have to be any more invasive than some of the food production and research tools used by any organic farmer. Indeed, AI has much to offer such a farmer in terms of boosting nutrient density in crops, growing hardier crops – and potentially nutrient bioavailability in end-products.

It is true there remain relatively few studies involving AI and nutrition – and this is a current limitation that AI's critics frequently use against it.

But the number of studies is growing fast. A PubMed enquiry for "nutrition and artificial intelligence" returns just 112 results, but 85 of those research papers have been published in the past three years.

AI law, bias, and database sharing

More generally, regulators are already imposing limits on the use of AI, such as the recently introduced AI Act in the EU, which attempts to rank and control use of

AI by perceived risk.[37] Many other jurisdictions are considering similar types of legislation.

Precision nutrition companies utilising AI to aid in the delivery of nutrition advice should be wary of how their advice interacts with official dietary guidelines, or issuing dieting guidance that could compromise health outcomes.[38]

This is something that is already widely occurring from the increasing numbers of people seeking dietary advice directly from AI chatbots like ChatGPT or Google Genesis (formerly Bard).[39]

The potential for economic, ethnic, or gender bias to be built into AI algorithms is another ever-present concern wherever AI is being utilised in any field.

"To date, only a limited amount of research has been published in this area," wrote US-based researchers.[40] "Acknowledging the great potential of AI to improve the future of healthcare and regulatory science, we would like to continue returning to AI-related ethical issues – including bias – and hope to see more research advances in measuring and mitigating potential biases from various sources."

Pasinetti, from the Icahn School of Medicine at Mount Sinai, suggested that one of the issues to watch will be the proliferation of bespoke AI-driven info ecosystems.

He said: "While these models show promise, they are still in early stages of development. One of the largest pitfalls is the lack of a standard to compare one system to another, making it hard to assess the validity of experimental data."

> "While these models show promise, they are still in early stages of development."
>
> Professor Giulio Maria Pasinetti, Icahn School of Medicine at Mount Sinai

Key takeaways

- **AI is enhancing nutrient bioavailability potential. It helps predict absorption, design targeted delivery systems, and optimise formulations, potentially leading to more effective and personalised supplements.**

- **AI is helping personalised/precision nutrition deliver on its promise. By processing data points such as genetics, microbiome, and dietary habits, for example, AI can boost the accuracy and potency of nutritional intervention advice.**

- **AI works fast and learns fast. While its outcomes may vary, it works incredibly quickly, with the potential to significantly shorten NPD timeframes.**

- **AI has ethical considerations. Potential biases in algorithms, limitations of AI-driven advice, and data privacy concerns need to be addressed for responsible implementation.**

- **AI is still a nascent technology. Though promising, further research and regulation are crucial to ensure the use of AI in food/supplement formulation and personalised nutrition reaches its potential.**

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