# PLANTS: QUESTIONS FOR THE FUTURE

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The global population mainly relies on animals to convert plants into dairy milk, eggs, and meat. In the future, a smarter approach will prevail, with meat made from plants, or milk and egg albumen protein produced via precision fermentation. These emerging technologies are expected to ultimately transform the global food system, offering significant environmental, ecological, and health advantages: no hormones, no steroids, fewer pathogens and antibiotics, reduced greenhouse gas emissions, preserved water resources, and decreased land use. Will these predictions become reality, or will they be dismissed as utopian wishful thinking?


By 2050, global meat consumption is expected to increase by an astounding 50 percent compared to 2024. This surge will place enormous environmental and ecological pressure on livestock farming. Harvested crops will face growing competition from both animal feed and human nutrition. These two pathways are on a collision course, and something will have to give sooner or later.

Relatively speaking, the future of food may gradually shift toward less animal-slaughtered meat and more animal-free "cow-less" milk, egg-free albumen, and plant-based meat consumption. Moving forward, traditional methods of producing animal proteins—such as intensive farming of livestock and dairy cows—will struggle to meet the rapidly growing global demand for protein.

## Change is Not a Choice

Plant-based dietary habits are not just about veganism; they represent a green evolution of social values, including animal welfare, sustainability, health, and proactive well-being. Plant-based protein will become a cornerstone of the future food industry. Plant-friendly claims often cover ethics, climate change, environmental stewardship, and resource conservation. Furthermore, consumers will increasingly favor recyclable packaging and animal welfare, as well as innovative technologies like molecular farming, upcycling of food waste streams, and biomass (mycoprotein) cultivation. These advancements will soon become integral to food protein portfolios.

Artificial Intelligence (AI) and Machine Learning Algorithms (MLA) are unlocking unprecedented insights into the biological connections between bioactive compounds found in plants and their impact on human health. It is estimated that there are approximately ten million bioactive compounds in the plant kingdom that can benefit humanity, accelerating the shift toward a healthier, regenerative food future. AI is a promising tool for deepening our molecular understanding of plants to nourish and sustain human health, rather than focusing solely on their contributions to disease.

## There is a Limit to Animal Harvest Growth

Moving forward, sustainable livestock intensification—with heavier carcass weights and improved feed-to-lean meat ratios—will be critical to balancing food security. Despite progress in animal welfare and livestock management, the world cannot continue to push

conventional meat production to future astronomical levels without facing serious repercussions.

Every single week, over a billion animals are slaughtered globally for human consumption. When calculated per minute, this amounts to approximately 120,000 chickens, 2,800 hogs, 940 sheep, 800 goats, and 570 cattle. For perspective, an astounding 520,000 hogs are slaughtered daily in North America.

Although current meat consumption in the Western world is at an all-time high, consumers are beginning to shift from eating pork and beef to poultry. From another perspective, Americans consumed approximately 35 percent less beef between 1990 and 2023, while their chicken consumption more than doubled, and pork consumption remained steady. Notably, global beef production appears to have paused in the U.S. In 2023, the number of cattle in America fell to its lowest point in decades. According to the U.S. Department of Agriculture (USDA), the nationwide beef cattle inventory in 2023 dropped to 28.2 million—the lowest level since the 1970s, down 2 percent from 2022. Total U.S. cattle and calf inventory hit its lowest level since 1951. Agricultural economists attribute this to persistent drought since 2020, high input costs, and runaway inflation, which have pressured both cattle farmers and consumers.

Despite these economic and environmental setbacks, U.S. demand for premium beef products like roast beef and hot dogs remained strong among affluent consumers. Meanwhile, those at the lower end of the economic spectrum have begun purchasing cheaper protein alternatives like chicken-formulated foods. This shift is exemplified by McDonald's U.S. introducing the "Big Mac Chicken" sandwich to reduce dependence on high-priced beef.



## Taste Challenges

The single biggest barrier to the sustained growth of plant-based meat consumption is taste. Bio-purification technologies based on fermentation principles are emerging as methods to remove off-flavors and unwanted characteristics in plant protein ingredients. Additionally, reducing anti-nutritional compounds and unwanted phytoestrogens is crucial. For example, the noticeable "beany" flavor caused by hexanal in legume-based proteins can be largely eliminated through targeted bio-purification fermentation technologies.

Current options for replicating animal fat rely heavily on less healthy saturated fats such as palm oil. Moreover, the texture and lingering aftertaste of plant-based meats are known barriers for consumers seeking alternatives. Membrane filtration technology offers the potential to remove the impurities in plant proteins that contribute to off-flavors and undesirable colors. However, flavoring ingredient systems are typically the most expensive components in plant protein- formulated foods.

## Plant Meat: Has the Hybrid Future Arrived?

To create a healthy, humane, and sustainable food supply, current food systems must transition away from factory- farmed animal production and slowly move toward other methods, such as molecular farming and precision fermentation. Achieving these goals will require a multidisciplinary approach.

How much longer can fast food chains like McDonald's and Burger King continue to claim "100% Pure Beef" for their burgers? The question is not "if" but "when"

the world will reach the point where the use of lean full-muscle meat in products like sausages and hamburgers can no longer be sustained for mass consumption. A great example of making food both more affordable and healthier is McDonald's Philippines' best-selling "McDo burger," which blends 30 percent beef with 70 percent plant-based ingredients. To meet health and price objectives, meat processors must embrace hybrid meat products that incorporate plant protein solutions. Ultimately, the economics of scale will reduce the price of plant protein-formulated foods. However, the global plant-based meat segment still has a long way to go to catch up with conventionally processed meat products.

## Flexitarians: A Game-Changing Development

Living a plant-based lifestyle no longer means eliminating all animal products or cutting out meat consumption entirely. A plant-based lifestyle is no longer synonymous with veganism or vegetarianism. The primary reason is that a growing number of consumers identifying with plant-based lifestyles are often flexitarians—those who choose to eat fewer animal protein-based foods but do not eliminate them entirely.

Although many affluent consumers are actively reducing their meat intake, they often avoid labeling themselves in a specific category. This suggests a broader market for plant-based protein products beyond those who identify as vegetarians. It is estimated that more than 90 percent of the core customers of plant-based companies like Garden Gourmet (Nestlé), Beyond Meat, Impossible Foods, Quorn, and Valess are flexitarians, not vegans or vegetarians.

Compared to men aged 45-75, younger generations are much more inclined to reduce their meat consumption and explore plant-based alternatives. Older men, in particular, tend to have fixed mindsets and are reluctant to give up foods they are accustomed to. It is somewhat surprising that meat consumption remains steady in most developed countries, while sales of plant-based meat products have plateaued or declined. This suggests that a true shift away from animal meat has yet to materialize, which could be seen as a lack of progress toward healthier, more sustainable diets from the perspective of the plant protein industry.


In the UK, it is estimated that there are around 24 million flexitarians—those who still enjoy meat but are open to substituting it with plant-based options. Many more people are interested in incorporating some elements of a plant-based diet, even if they are not willing to commit full-time. Clearly, plant-based food choices appeal more to the broader flexitarian consumer base than to strict vegetarians or vegans. Consumers are increasingly aware that reducing meat and dairy consumption is seen as the most significant way to lessen the environmental impact on the planet. Although plant-based breaded chicken products are a growth leader, beef analogue burgers remain the most popular product in the plant-meat category. Beef is, by far, the world's best-selling meat product to simulate.

Food retailers in the UK, like Sainsbury's, Tesco, Marks & Spencer, and Waitrose, have dedicated vegetarian sections— stocking alternative products in meat aisles—and focus on delivering high-quality plant-based foods, along with a wide range of plant milk products like Oatly. However, sales numbers for 2023 and projected 2024 indicate that the UK and EU market for plant-based foods has stalled, and the once double-digit growth has largely disappeared. Both in the EU and UK, supermarkets are adopting hard-bargaining tactics that have driven some plant-based companies into receivership or administration. VBites is one example, although Heather Mills'

company has restarted operations and is actively promoting multi-buy offers, slashing prices by up to 70 percent. Similarly, low-cost supermarkets such as Aldi and Lidl have repositioned plant-based products under their own labels, further reducing margins for plant meat suppliers.

## Balanced Nutrition is Key

Consumers should also be aware that plant-based foods may contain lower-quality protein, meaning these nutrients must be obtained elsewhere. Simply eating plants and nuts is not always sufficient. In most cases, restricting entire food groups can be a red flag for nutrient deficiency or may signal an eating disorder. Therefore, it is crucial to ensure that all necessary nutrients, as well as potentially supplemented bio- nutrients, are present in daily diets to prevent chronic conditions.

Although the popularity of meat and dairy alternatives is partly fueled by their perceived health and muscle-promoting benefits, transitioning from an animal-based diet to a plant- based one may not be as straightforward as it seems. A higher volume of plants needs to be consumed to match the concentration and density of protein and amino acids found in animal-derived proteins. Moreover, it can be challenging to balance the amino acids from various plant proteins to achieve the highest possible nutritional protein quality.

## Plants: Anti-Nutrients

Plant proteins may be less digestible due to anti-nutritional factors or plant matrix effects. However, some compounds that reduce protein digestibility can offer health benefits, making the discussion around digestive health complex.

Anti-nutritional factors in plants like enzyme inhibitors and acids, which must be removed before human consumption through methods such as centrifuging, thermal treatment, and fermentation. Soymilk, miso, and tofu are good examples of fermented products that eliminate or regulate excessive levels of unwanted phyto-compounds.

Significant technological advancements have been made to remove unwanted plant micro-components. One remaining issue is the presence of isoflavones in soy protein, which can mimic the estrogen hormone. When consumed in large quantities, these compounds can have detrimental effects on the female reproductive system and may even lead to conditions like undescended testicles in male newborns.

These observations should not be misinterpreted as anti-plant. On the contrary, they highlight the importance of a diet that includes consumption of both plant and animal proteins, providing a more balanced nutritional profile than relying solely on one source.

## Plant Diet: Vitamin & Mineral Alert

While predominantly plant-based diets offer numerous benefits, they can also lead to certain health problems. Specifically, strict vegans who avoid all animal products may be at risk of micronutrient deficiencies. Vitamin B12, which is essential for building red blood cells, repairing DNA, and protecting the brain, is particularly at risk of being deficient.

New food trends can have unforeseen consequences, such as deficiencies in nutrients like iron, choline, and vitamin B12 among vegans. Studies have reported that 80 percent of vegan mothers in Germany and Switzerland are deficient in these nutrients. When meat and dairy are eliminated from the diet, extra care must be taken to ensure adequate

intake of protein, calcium, and vitamin B12. Diagnosing vitamin B12 deficiency can be difficult, as it presents with vague symptoms like fatigue, irritability, memory lapses, and pale skin. Over time, the deficiency can lead to more serious issues, including vision loss, psychosis, imbalance, and even paralysis. Additionally, vitamin B12 deficiency is linked to an increased risk of dementia, depression, cardiovascular disease, stroke, and certain cancers.

Expectant mothers with B12 deficiency are up to five times more likely to give birth to children with serious birth defects, especially those involving the brain or spinal cord. B12 deficiency can also affect the elderly, people taking heartburn medication that reduces stomach acids, individuals with celiac or Crohn's disease, and those who have undergone gastric bypass surgery. For these individuals, B12 supplements in pill form or injections are necessary to prevent slow-progressing health issues. Vitamin B12 supplements are safe and affordable, while regular injections offer an alternative for those with absorption problems. For strict vegans, getting enough vitamin B12 from diet alone can be nearly impossible. It's estimated that about half of all dedicated vegans suffer from clinical vitamin B12 deficiency.

While it is possible to live a healthy vegan lifestyle with careful planning, scaling this approach to a nationwide level presents challenges. In any given society, there are always subgroups of people who require different dietary considerations. Vegans should consider to permanently take B12 supplements and select fortified foods that are rich in essential


or critical nutrients, particularly indispensable amino acids, long-chain omega-3 fatty acids, vitamins like riboflavin, vitamin D, and B12, as well as minerals like calcium, iron, potassium, iodine, zinc, and selenium. These considerations are especially important for pregnant or breastfeeding women, as well as for infants, children, and adolescents at all stages of growth.

People in developed countries or affluent societies typically get enough vitamins A and C, but their diets may fall short on vitamin D and potassium. Both of these nutrients are vital for good health: Vitamin D helps the body absorb calcium to maintain strong bones, while potassium helps lower blood pressure, particularly in those with hypertension. Potassium is also crucial for those engaging in intense physical activity.

## The Choline Concern

People who shift toward plant-based foods and significantly reduce their intake of meat, dairy, eggs, and fish may risk further lowering their intake of choline. Choline deficiency can cause muscle and liver diseases and contribute to cardiovascular problems, dementia, and neural tube defects in infants.

Choline is a critical nutrient needed for neurocognition, lipid metabolism, liver function, and homocysteine regulation. It is also important for memory, mood, and muscle control. Like omega-3 fatty acids, choline is an essential nutrient that the body cannot produce in sufficient amounts. Choline deficiency is linked to liver disease, cognitive decline, and potential neurological disorders. A lack of choline can also lead to irregularities in blood fat metabolism and increased free radical damage to cells.

The U.S. Institute of Medicine recommends a minimum daily intake of 425mg/day for women and 550mg/day for men. Pregnant and breastfeeding women require at least 550mg/day due to choline's critical role in fetal development. While a plant-based diet can provide health and environmental benefits, consumers should not become complacent about nutritional security. People transitioning to a strict vegan diet must carefully monitor both their vitamin B12 and choline intake. Though a vegetarian or vegan diet can be healthy, the lack of vitamin B12 and choline suggests that about one in ten people may be under-consuming these essential nutrients.

## Growing Children

Medical professionals are increasingly alert to the potential negative side effects of a vegan diet, particularly for children. Pediatricians are seeing more infants and young children suffering from severe deficiencies that may have long-term health consequences as they grow.

The general rule is that the more restrictive the diet, the greater the nutritional risk. A strict vegan or vegetarian dietary pattern may be nutritionally challenging, especially for children. Possible deficiencies can have significant implications for childhood development, including skeletal growth and brain function. For example, iron deficiency can cause anemia, which manifests as fatigue, slow growth, behavioral issues, and rapid breathing. To avoid these nutritional risks, parents must be well-informed and ensure that a vegan or vegetarian diet is well-balanced, containing appropriate amounts of essential amino acids, vitamins, minerals, and trace elements.