

Perspective: Unpacking the Wicked Challenges for Alternative Proteins in the United States: Can Highly Processed Plant-Based and Cell-Cultured Food and Beverage Products Support Healthy and Sustainable Diets and Food Systems?

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ABSTRACT

Over the past decade, a plethora of alternative protein (AP) products has entered the US food system as plant-based food and beverage products. These AP products, which include plant-based meat and dairy alternatives and cell-cultured meat and seafood products, are being developed for the marketplace to simulate the appearance, texture, taste, and flavor and nutritional profiles of animal products. The new generation of AP plant-based and cell-cultured food and beverage products are part of a market-driven narrative that has embraced technology to address future human health, environmental, ethical, and planetary health challenges. This perspective article synthesizes evidence about the benefits of adopting minimally processed plant-based diets that support sustainable food systems and human and planetary health. Thereafter, it examines 4 wicked challenges related to AP products in the US context that include 1) a confusing marketing landscape for the public; 2) diverse views and varying acceptance among consumers about the health and environmental benefits of these products; 3) inadequate education and labeling provided by federal agencies to enable consumers to understand how these may support healthy sustainable diets; and 4) slow federal policy and regulatory actions to address the range of AP products and provide industry guidance. The article concludes with suggested policies and actions for government agencies and food system actors to address these challenges. Future research and actions are needed to balance the human health, equity, animal welfare, and economic viability goals and to clarify how AP products may support safe, healthy, sustainable diets and food systems. *Adv Nutr* 2022;13:38–47.

Statement of Significance: This perspective article describes the policy implications for a new generation of highly processed, alternative protein (AP) plant-based and cell-cultured food and beverage products that have rapidly entered the US marketplace over the past decade. This is an important topic that has not been explored in depth by the journal from a policy perspective, although other ASN journals have covered this topic in various ways in recent years. The unique contribution of this article is that it examines 4 challenges related to AP products in the US context concerning consumer acceptance, education needs, marketing trends, labeling policies, and regulatory agency oversight. After examining these 4 challenges, the article suggests actions for federal government and other food system actors to address AP products, and clarify how they may support healthy and sustainable dietary patterns and food systems.

Keywords: plant-based foods, cell-cultured meat, alternative proteins, sustainable diet, dietary guidelines, public health, planetary health

Introduction

Traditional plant-based sources of dietary proteins (i.e., vegetables, beans, legumes, nuts, and seeds) that are made into products (i.e., tofu, tempeh, hummus, and seitan) have been used by cultures worldwide for centuries as healthy complements to animal foods to meet human protein needs to sustain health (1). Since 2010, a plethora of alternative protein (AP) products have been created, which include

plant-based meat and dairy alternatives and cell-cultured meat and seafood, tend to be more highly processed than the traditional products, and are being developed for the marketplace to simulate the appearance, texture, taste, and flavor and nutritional profiles of animal products (1–3).

These products have expanded rapidly in the United States' food system, and the US plant-based retail market was worth \$7 billion in 2020 (4), of which \$1.4 billion was

plant-based meat analogs and \$2.5 billion was plant-based milk products (4). In 2020, venture capitalist investments in global AP products exceeded \$1 billion, and revenues are predicted to rise for the global AP dairy (to \$36.7 billion) and AP meat (to \$8.3 billion) markets by 2025 (2).

AP plant-based products are made either from 100% plant sources or by combining plant materials with live-stock sources (2, 5). Many of these products would be classified as ultra-processed by the NOVA food classification system (6). NOVA is not an acronym but rather a Brazilian-language term that describes a food classification system that was developed by researchers at the University of São Paulo, Brazil. NOVA advises people on selecting food and beverage products from 4 distinct groups based on the extent and purpose of the processing to promote a healthy diet. The 4 groups include 1) unprocessed or minimally processed foods, 2) processed culinary ingredients, 3) processed foods, and 4) ultra-processed foods (6). AP cell-cultured products are also called “clean” meat, milk, chicken, egg, and seafood, and produced in vitro by culturing animal cells in a suitable medium (1–4). Government regulatory agencies have not yet approved AP cell-cultured food products for the US marketplace (7).

These AP products have fostered ethical and policy debates about whether market-driven solutions that encourage AP products manufactured by transnational firms and distributed within large-scale, industrialized global agri-food systems can support healthy, equitable, and sustainable diets and food systems (8–10). Moreover, a large proportion of these products are highly processed, may have poor nutritional content, and their long-term human health effects are unknown (8–10).

This perspective synthesizes evidence about the benefits of adopting minimally processed plant-based diets to support sustainable food systems. Despite the increasing popularity of AP products, this article examines 4 wicked challenges (11) in the US context including 1) the current marketing landscape for AP compared with conventional protein products that confuses the public; 2) consumers’ diverse views about the health and environmental benefits of AP products compared with conventional livestock protein products; 3) federal agencies’ inadequate provision of education and labeling guidance for consumers to understand how AP products support healthy sustainable diets; and 4) the slow federal

policy and regulatory actions to address AP products, including industry guidance for cell-cultured products. [A wicked challenge is a problem about the nature and framing of which there is no agreement among actors; the causes and solutions to address the challenge vary and are judged by many actors; there are no best practices to guide policy decisions; and solutions are determined by a specific policy context (11).] The article concludes with suggested policies and actions for government and food system actors to address these challenges.

Benefits of Healthy Sustainable Diets and Food Systems for People and Planet

Sustainable diets and sustainable eating patterns aspire to balance many goals to promote human health and well-being; support biodiversity and environmental stewardship and respond to climate change challenges; ensure social equity and fair trade; encourage eco-friendly, locally, regionally, and seasonally produced foods; accommodate cultural heritage and cooking skills; and meet the food and nutrient needs of populations while promoting food and nutrition security (12).

If populations were to adopt healthy sustainable dietary patterns on a large scale, countries would be better positioned to align their national food systems to produce health and environmental benefits consonant with their international commitments, including the 2030 UN Sustainable Development Goals, 2015 Paris Agreement to reduce the impact of human-induced climate change on planetary health, and 2017 Aichi Convention on Biodiversity (13). The World Wildlife Fund described the need to shift global food systems toward plant-based diets to reverse biodiversity loss, encourage people to live within a global carbon budget, reduce greenhouse gas emissions (GHGE), feed people on existing land, and optimize crop yields (14).

There is currently a lack of scientific consensus to inform dietary guidelines on optimal sources and amounts of animal and plant-based protein sources to promote healthy diets (15). Debate continues about the association between processed and red meat intake and colorectal cancer risk depending on study design, type of meat, and cooking methods (16). A nuanced discussion about the potential health benefits of poultry, seafood, and dairy is beyond this article. However, robust evidence suggests that a plant-based diet comprised of minimally processed whole foods is associated with a lower all-cause mortality risk for noncommunicable diseases (NCDs) including type 2 diabetes and cardiovascular diseases (17, 18); and may reduce global GHGE, biodiversity loss and species extinction, and other environmental externalities (19).

People who adopt a vegetarian or vegan dietary pattern comprised of minimally processed, diverse plant-based foods (i.e., fresh fruits and vegetables, whole grains, legumes and beans, nuts and seeds) are more likely to reduce NCD risks while promoting co-benefits for environmental and planetary health (20–22). Flexitarian and healthy Mediterranean dietary patterns with limited amounts of lean, unprocessed,

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Abbreviations used: AP, alternative protein; DGA, Dietary Guidelines for Americans; DGAC, Dietary Guidelines Advisory Committee; FOP, front-of-package; FTC, Federal Trade Commission; GHGE, greenhouse gas emissions; IFIC, International Food Information Council; LCA, life cycle assessment; NCBA, National Cattlemen’s Beef Association; NCD, noncommunicable disease.

or minimally processed red meat, fish, or seafood without excessive calories and sodium are associated with better weight management outcomes and reduced obesity and cardiovascular disease risks (23–25). A 25% reduction in total protein combined with a 25% dietary shift from animal to plant proteins could reduce GHGE by 40% and water use by 10% (26).

The Dietary Guidelines for Americans (DGA) 2020–2025 recommended the healthy US-style, Mediterranean-style, and Vegetarian dietary patterns to prevent diet-related NCDs (27). Yet >80% of Americans do not meet these dietary patterns and DGA targets for fruits, vegetables, and dairy; and more than half neither consumes the recommended amount of whole grains nor diversifies their protein to include plant and animal sources (27).

An NHANES (1999–2016) analysis over 18 y showed that US adults' intake of processed meats (i.e., luncheon meats, ham, sausages, hot dogs, and bacon) remained stable; unprocessed red meat intake declined; fish and seafood intake remained stable; and poultry intake increased (28). Most Americans had an average Healthy Eating Index score of 59 in 2013–2014 and 57 in 2015–2016, which are substantially below the USDA's high diet quality score of 80–100 (27, 29).

Healthy biomarkers are more strongly associated with high diet quality (i.e., minimally processed nutrient-dense food groups) rather than diet categories (i.e., vegetarian and omnivore) (30). Plant-based vegetarian or flexitarian diets may include highly processed, energy-dense products with excessive calories, fat, and sodium (31). Therefore, replacing minimally processed plant foods and modest amounts of animal-source foods with a large amount of highly processed AP plant-based foods may reduce overall diet quality, nutrient density, and dietary diversity (32).

There are differences between the environmental impacts of conventional livestock, AP plant-based products, and cell-cultured meat products. A life cycle assessment (LCA) that compared conventional livestock production with cell-cultured biomass cultivation found laboratory-produced meats to have higher energy-intensity inputs despite being more economically efficient, and to present trade-offs for large-scale production and environmental sustainability labeling (33). By comparison, an LCA of the Beyond Meat burger with conventional beef found a 90% reduction in GHGE, land impact, and water use (34). Thus, it is important to examine many concurrent challenges associated with highly processed, AP plant-based products that affect diet quality, human health, and the environmental sustainability of dietary patterns and food systems. The next section examines 4 challenges for AP plant-based and cell-cultured products.

Challenge 1: Confusing Marketing Landscape for AP Compared with Conventional Protein Products

The first wicked challenge is that American consumers must navigate thousands of processed food and beverage products

daily in food environments to decide what is affordable, tasty, convenient, healthy, and environmentally sustainable. The competitive advertising and marketing campaigns represent billions of dollars for businesses operating in the US marketplace that encourage consumers to eat conventional animal products, mixed or “blended” AP and animal products, and 100% AP plant-based products.

Sexton et al. (8) identified 5 narratives in a “typology of promises” used by the AP plant-based manufacturers and retailers that include healthier bodies; feeding the world, now and forever; good for animals and the environment; using technology to control inputs and methods for sale; and tastes like an animal (8). They also described 3 counter-marketing narratives: AP products are not a serious threat, they are fake foods, and they are not legally defined (8).

Between 2015 and 2021, many US private-sector actors promoted advertising and marketing messages about their products that highlighted various aspects of health and sustainable, ethical, and profitable food systems. Beyond Meat launched the “Cooks and Looks Like a Burger” campaign (35) and Impossible Foods launched the “We Are Meat” campaign targeting meat eaters (36, 37). Lightlife Foods launched the “Clean Break” campaign criticizing its AP competitors' products as containing “Hyper-processed ingredients, genetically modified organisms, unnecessary additives, fillers and fake blood” and emphasizing that “Plant-based burgers should be developed in a kitchen, not a lab” (38). Danone North America's “Silk™: Milk of the Land” campaign featured how almonds are grown (but not processed) into almond milk (39).

Food manufacturers are also producing their own AP plant-based products including Tyson's Raised and Rooted™ plant and meat-blended brand (40), Cargill's PlantEver™ brand (41), and Conagra's Gardein™ plant-based burger brand (42, 43). General Mills has invested in Good Catch, a venture firm to market plant-based fish burgers (44), and Nestlé is exploring a partnership to produce and combine cell-cultured with plant-based meat to maximize taste (45). AP manufacturers are partnering with US manufacturers and retailers including Beyond Meat and PepsiCo's PLANet partnership to make plant-based snacks (46), Beyond Meat's partnership with Yum Brands! (KFC and Pizza Hut) and McDonalds to sell plant-based burgers (47), and Impossible Foods' partnership with Burger King to market the Impossible Whopper™ (48).

Industry trade associations, such as the National Fluid Milk Processor Promotion Board, relaunched the “Got Milk?” campaign in 2020 to reach multicultural youth, and partnered with the US Olympic Committee to promote the virtues of drinking milk (49–51). The National Cattlemen's Beef Association (NCBA) launched the “Fake Meat” campaign (52) that criticized AP plant-based products, and updated its “Beef. It's What's for Dinner” with a pro-meat sustainability campaign in 2021 featuring farmers using digital technology through its “Protecting Beef by Rethinking the Ranch” social media campaign (53). Although these health and sustainability claims are widespread, the Federal

Trade Commission (FTC) has taken limited actions to regulate health and environmental sustainability advertising claims and marketing campaigns to ensure that these are truthful and nonmisleading for consumers (54).

Challenge 2: Consumers Have Diverse Views on AP Plant-Based and Cell-Cultured Products

The second wicked challenge is the diversity of views about the health and sustainability benefits of AP plant-based and cell-cultured products compared with conventional animal products. A national survey of the views of American adults ($n = 1000$) about climate change and diet found that more than two-thirds (70%) do not or rarely talk about the climate impact of the foods they eat; 67% would try plant-based foods if they taste better than animal proteins; and 63% would eat more plant-based foods if they cost less than meat (55).

A 2019 Gallup Survey ($n > 1000$ adults) found that half of Americans are familiar with AP plant-based branded products, including Impossible and Beyond Meat burgers, sold in US grocery stores and chain restaurants; 40% reported having eaten these products; and 60% aged 18–50 y expressed that they would eat these products again (56). A 2020 International Food Information Council (IFIC) Foundation survey of American adults ($n = 1000$) described reasons why consumers select plant-based meat alternative products that included people liked the sensory qualities and taste (53%), the texture is similar to meat (35%), and they could prepare it similarly to meat (29%) (57); and nearly half (45%) of the adults viewed AP plant-based products as healthier than animal meat after reading the Nutrition Facts and ingredient labels (57).

The Nutrition Facts and ingredient labels provide information about nutrients of concern (i.e., sodium and saturated fat) with the percentage Reference Daily Intake per serving for AP plant-based meat products but do not provide information about processing. A separate survey of American consumers ($n = 1800$) about their preference for beef compared with meat analogs found that 72% preferred farm-raised beef, and a majority were opposed to AP plant-based and cell-cultured “clean meat” products using a “beef” label (58).

Ethnographic research on Americans about AP products found diverse views on how AP products support human health or environmental sustainability for planetary health (59). Another study found that Americans have different views about how the terms healthy, sustainable, trustworthy, and ethical relate to conventional cow milk and dairy products compared with AP plant-based products that will require conventional producers to clarify their sustainability messages if they want to compete with AP products in the US marketplace (60).

AP product manufacturers and retailers use clean labels to highlight plant-based features that appeal to consumers more than meat-free or vegan claims; and they use “free-from” claims (i.e., soy, dairy, and gluten) to promote the absence of ingredients, which differ from organic, natural, and healthy

claims (61). Lacy-Nichols et al. (62) examined ~1400 front-of-package (FOP) labeling claims for 216 plant-based meat products and found a majority (94%) used nutrient claims to compare these products with meat; 74% used free-from claims for genetically modified organisms; 63% used a plant-based claim; and no products indicated level of processing (62). The 2020 IFIC Foundation’s Food & Health Survey ($n = 1000$) found that Americans ranked price, taste, and convenience higher than health and environmental sustainability as influences on their purchasing and eating decisions (63). Americans who reported reducing red meat and processed meat intake were motivated by cost, health, and income, not environmental sustainability concerns (64).

Challenge 3: Inadequate Guidance on How AP Products Support Healthy Sustainable Diets

The third wicked challenge is inadequate policy guidance from government agencies on highly processed plant-based food and beverage products. The 2020 Dietary Guidelines Advisory Committee (DGAC) report (65) did not acknowledge the extent (~60%) or major sources of highly processed products in the US food supply (66). The DGAC report (65) did not address the diet quality or health effects of people consuming highly processed, AP plant-based food products with altered food matrixes that may affect how these products are metabolized; and that these products contain excessive nutrients of concern, additives, and flavorings to maximize sensory appeal (6, 67, 68).

Harnack et al. (69) analyzed the nutrient profiles of 37 AP plant-based beef products and showed they were higher in sodium and contained less protein, zinc, and vitamin B-12 than ground beef. Although many AP plant-based products are considered nutrient-dense, there is no US labeling symbol that enables consumers to easily identify them as highly processed products. Another study (70) found that conventional and AP plant-based meat analog products are not nutritionally interchangeable because each has unique, different compositions of metabolites essential for biological functions in the human body, despite comparable Nutrition Facts panels.

The DGA 2020–2025 report recommended that people adopt a healthy dietary pattern higher in lean meats and poultry, seafood, and nuts and lower in red meat and processed meats (27). Yet the DGA did not explicitly advise Americans to select minimally processed foods or avoid highly processed foods, including AP plant-based meat or nondairy products such as nondairy almond, cashew, coconut, and oat milks.

The DGAC members published a separate review, which concluded that diets low in animal-source foods have lower environmental impact than the current Western diet; however, the DGAC 2020 did not mention climate change or a planetary health diet because it was unlikely to have been included in the final report (71). Unlike guidelines in other countries, the DGA lack healthy beverage recommendations

across the life span; do not recommend unsweetened plant-based nondairy products over sweetened versions; nor do they provide environmentally sustainable eating guidelines (71, 72).

Challenge 4: Slow Federal Regulatory Actions to Address the Range of AP Products

The fourth wicked challenge is that the US FDA is still working on its Nutrition Innovation Strategy to 1) develop food standards of identity and update ingredient lists, 2) assess feedback from a public consultancy on the use of “natural” and “healthy” product claims, and 3) conduct research for an FOP “healthy” symbol for packaged products including plant-based analogs (73). The USDA regulates animal products including pork, beef, poultry, eggs, fish, and seafood. In 2019, the FDA and USDA announced an agreement to jointly regulate cell-cultured food products from cell lines of livestock and poultry to promote accurate labeling and safe products (74). The FDA will regulate the collection and growth of cultured cells, whereas the USDA will regulate meat production after cells are harvested, including the processing of cells into market-ready products (74).

A 2020 Government Accountability Office report issued to a House Committee described AP cell-cultured meats as a “business venture still in the research and development phase” (75). For the FDA and USDA to approve cell-cultured food products, manufacturers must provide information about animal tissue collection, growth medium, genetic engineering, scaffolding, production methods, product safety and composition, and antibiotic content (75). Even after cell-cultured products are approved, they must compete with other branded AP plant-based products, consumers may not accept them, and it is unclear whether cell-cultured products will be approved for Kosher or Halal labeling to comply with Jewish and Islamic dietary restrictions (76).

In the absence of federal regulatory guidance for AP products, meat and milk producers are using litigation to contest and pre-empt the labeling and marketing of plant-based products in states. Legal analysts have described the complex US state labeling situation as “volatile” (77). Interest groups are influencing state legislators, and judges are deciding product labeling laws through litigation to limit or prevent AP plant-based product marketing in many states (77).

Between 2018 and 2020, 30 US states considered legislation to limit how plant-based protein products could be labeled as “sausage, burger and bacon” (77, 78). Missouri enacted the first law (2018) that prohibited AP plant-based manufacturers from misrepresenting a product as meat if not derived from harvested production livestock or poultry that could be punishable with a \$1000 fine and a year in prison (79). Louisiana’s Truth in Labeling of Food Products Act (2019) and Oklahoma’s Meat Consumer Protection Act (2020) prohibit AP plant-based product labeling that suggests animal products unless manufacturers add disclosures (77, 78). The NCBA beef industry trade association lobbied

US Senators to gain their support for the Real MEAT Act national legislation (2018–2020) (52) to pre-empt plant-based food product labeling in states where restrictive laws have not succeeded. New York and Texas introduced bills in the state legislatures during 2021 that define meat and milk products as derived from livestock or mammals, and prohibit the use of these terms for AP plant-based products (80).

Milk producers have criticized the FDA for not using its own standards of identity for milk products, defined as the lacteal secretion of cows. In 2019, Danone North America’s Silk non-dairy Almond Breeze was sued in a US circuit court as mislabeled and called “imitation milk”; however, the judge ruled that consumers were not misled by the plant-based milk labels (81). A 2021 House Appropriations Committee report encouraged the FDA to provide labeling guidelines for plant-based products and included \$5 million in the 2022 budget to support AP product research (82), and the FDA plans to issue guidance on nondairy milk product labeling by June 2022 (83).

Suggested Policies and Actions

The USDA’s DGA 2020–2025 (27) and MyPyramid encourage Americans to consume “lean protein—choose protein foods like beans, fish, lean meats and nuts” (84) but do not mention AP plant-based products. Consumer demand is growing for minimally processed, ready-to-eat meals and product labeling that align with planetary health dietary guidelines (85).

In May 2021, Impossible Foods announced a multimillion-dollar business deal with the USDA to launch a pilot school meals program to serve plant-based burgers to children in grades K-12 in 3 states starting in Fall 2021 (86). To qualify, AP products may use “soy or other vegetable protein sources with a biological quality of 80% of milk protein determined by a protein digestibility score” (86). This example raises the question about whether the USDA has adequate information to serve AP products to millions of US children through school meals.

Table 1 summarizes the wicked challenges and suggested policies and actions for various federal government agencies and other food system actors to address the range of AP products. To address the first challenge, the FDA, FTC, and USDA could collaborate to update the FTC’s 2012 “green” advertising standards for environmental sustainability claims and eco-sustainable labeling (54). The FDA and FTC should also enforce guidelines that ensure AP plant-based and cell-cultured product advertising and marketing claims and campaigns are truthful and nonmisleading to inform consumers’ choices in the US marketplace.

To address the second challenge, the USDA could clarify the agency’s position on minimally processed plant-based foods, fund research to clarify the role of AP products in national dietary guidelines, and investigate how these products may support healthy sustainable dietary patterns and food systems. US professional societies could also publish position statements based on evidence from other

TABLE 1 Challenges and suggested policies and actions for US government agencies and other actors to address AP products¹

Challenges	Policies and actions
1. Current US marketing landscape for AP compared with conventional livestock-derived protein products is confusing for the public	<ul style="list-style-type: none"> • The FDA, FTC, and USDA could collaborate to update the FTC’s 2012 “green” advertising standards for environmental sustainability claims and eco-sustainable food and beverage product labeling. • The FDA and FTC should enforce guidelines that ensure AP plant-based and cell-cultured product advertising and marketing claims and campaigns are truthful and nonmisleading to inform consumers’ choices in the US marketplace.
2. American consumers have diverse views and varying acceptance about the health and environmental benefits of AP plant-based and cell-cultured products compared with conventional livestock and other animal protein sources and products	<ul style="list-style-type: none"> • The USDA could clarify the agency’s position on minimally processed plant-based foods, fund research to clarify the role of AP products in national dietary guidelines, and investigate how these products may support healthy sustainable dietary patterns and food systems. • US professional societies could publish position statements based on evidence from other countries to encourage the USDA and HHS to incorporate environmental sustainability principles into the 2025 DGAC and DGA 2025–2030 report recommendations.
3. Federal government agencies have provided inadequate education and labeling for consumers to understand how AP products may support healthy sustainable diets	<ul style="list-style-type: none"> • The USDA could use rulemaking to conduct a public consultation to inform how AP product labeling and education may support healthy and sustainable dietary guidelines. • The USDA could develop digital education and social media marketing campaigns that adapt the DGA and MyPlate messages to encourage minimally processed plant foods that align with other public education efforts, such as the Produce for Better Health Foundation’s “Have a Plant” movement and the EAT–<i>Lancet</i> planetary health diet. • The CDC, FDA, and USDA could work with researchers, industry, and civil society organizations to communicate how AP products may support healthy and environmentally sustainable dietary guidelines for public food procurement.
4. Slow federal policy and regulatory actions to address the range of AP products	<ul style="list-style-type: none"> • The FDA, FTC, and USDA should use their institutional authority, and work with the US Congress, to enact national legislation to supersede and pre-empt different state laws that restrict AP plant-based product labeling and marketing. • The FDA and USDA should communicate the regulatory guidelines and timeline for approving cell-cultured food products to be sold in the US marketplace.

¹AP, alternative protein; DGA, Dietary Guidelines for Americans; DGAC, Dietary Guidelines Advisory Committee; FTC, Federal Trade Commission; HHS, Department of Health and Human Services.

countries to encourage the USDA and the Department of Health and Human Services to incorporate environmental sustainability principles into the 2025 DGAC and DGA 2025–2030 report recommendations (70, 87).

To address the third challenge, the USDA could use rulemaking to conduct a public consultation to elicit feedback on how AP products and food labeling may support healthy and environmentally sustainable dietary guidelines. The USDA could develop digital education and social media marketing campaigns that adapt the DGA and MyPlate messages to encourage minimally processed plant foods that align with other public education efforts such as the Produce for Better Health Foundation’s “Have a Plant” movement and the EAT–*Lancet* planetary health diet (70). The CDC, FDA, and USDA could also collaborate with researchers, industry, and civil society organizations to communicate how AP products may support healthy and environmentally sustainable dietary guidelines for public food procurement.

To address the fourth challenge, the FDA, FTC, and USDA should use their institutional authority, and work with the US Congress, to enact national legislation to supersede and

pre-empt different state laws that restrict AP plant-based product labeling and marketing. In September 2021, the USDA published an advanced notice of proposed rulemaking to request public comments about the labeling of cell-cultured meat and poultry products to inform future labeling policy (88). This is an important step for federal agencies to communicate the plans and timeline for regulatory guidelines to approve cell-cultured food products for the U.S. marketplace.

Future technological advancements made by industry to produce AP plant-based and cell-cultured products will improve their quality and sensory profiles to promote versions that meet guidelines for health and environmental sustainability. All food system actors must help the public understand the differences in the extent of AP product processing (i.e., highly compared with minimally processed); the type of processing methods used (i.e., fermentation compared with produced in a laboratory or bioreactor); the different names used to market and label AP products; and how these factors relate to health and environmental eco-sustainability product labeling claims (i.e., carbon footprint, planet score,

ethical and local sourcing of plant-based ingredients) (85, 89).

Research is also needed on the scale-up economics of AP plant-based and cell-cultured products to show that they may compete with the pricing of conventional animal-source protein products (90), while balancing balance human health, food safety, economic viability, social equity and animal welfare goals. Finally, evaluations are needed to confirm whether these new products support an agri-food paradigm that aligns with President Biden's 2021 executive order to uplift small and medium farmers, strengthen community food systems, promote local and regional foods and seasonal eating, and prevent the further corporate consolidation of the U.S. food system (91).

Conclusion

The future of AP plant-based and cell-cultured food products is promising but uncertain. This perspective article examined 4 wicked challenges related to AP food and beverage products in the US context. A highly competitive and confusing marketing landscape currently exists for conventional livestock products compared with AP food and beverage analog products. US consumers have diverse views about AP products and are uncertain about how they support healthy and environmentally sustainable diets. Although consumer familiarity with and acceptance of AP products are growing, government regulatory agencies and industry must ensure product safety, healthfulness, quality, and affordability to Americans. Federal government agencies could work with private philanthropies, civil society organizations, and industry to fund research to clarify the role of AP products in national dietary guidelines, harmonize and standardize product labeling, and communicate how these products may support safe, healthy, sustainable dietary patterns and food systems.

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