Price-, Taste-, and Convenience-Competitive Plant-Based Meat Would Not Currently Replace Meat

Jacob R. Peacock

August 15, 2023

Executive summary

Plant-based meats, like the Beyond Sausage or Impossible Burger, and cultivated meats have become a source of **optimism for reducing animal-based meat usage**.

- **Public health, environmental, and animal welfare advocates** aim to mitigate the myriad harms of meat usage.
- The **price, taste, and convenience (PTC) hypothesis** posits that if plant-based meat is competitive with animal-based meat on these three criteria, the large majority of current consumers would replace animal-based meat with plant-based meat.
- The PTC hypothesis rests on the **premise that PTC *primarily* drive food choice.**

The **PTC hypothesis and premise are both likely false.**

- A majority of **current consumers would continue eating primarily animal-based meat** even if plant-based meats were PTC-competitive.
- **PTC do not mainly determine food choices** of current consumers; **social and psychological factors** also play important roles.
- Although not examined here, there **may exist other viable approaches** to drive the replacement of animal-based meats with plant-based meats.

There is **insufficient empirical evidence** to more precisely estimate or optimize the current (or future) impacts of plant-based meat. To rectify this, consider funding:

- Research measuring the **effects of plant-based meat sales on displacement of animal-based meat**.
- Research **comparing the effects of plant-based meats with other interventions** to reduce animal-based meat usage.
- **Informed (non-blinded) taste tests to benchmark current plant-based meats** and enable measurements of taste improvement over time.

Contents

Introduction

Plant-based meats, like the Beyond Sausage or Impossible Burger, and cultivated meats[1] have been identified as important means of reducing the public health, environmental, and animal welfare harms associated with animal-based meat production (Rubio et al., 2020). By providing competitive alternatives, these products might displace the consumption of animal-based meats. Since cultivated meats are not currently widely available on the public market, this paper will focus on plant-based meats, although many of the arguments might also apply to cultivated meats.

Animal welfare, environmental, and public health advocates believe plant-based meats present a valuable opportunity to mitigate significant negative externalities of industrial animal agriculture, like animal suffering, greenhouse gas emissions, and antimicrobial resistance. For example, Animal Charity Evaluators lists "[cultivated] and plant-based food tech" as a priority cause area (Animal Charity Evaluators, 2022b), and a 2018 survey of 30 animal advocacy leaders and researchers ranked creating plant-based (and cultivated) meats third (after only research and corporate outreach) in their top priorities (Savoie, 2018). Non-profits working to research and support plant-based and cultivated meat production have received millions of dollars in funding (Animal Charity Evaluators, 2022a; New Harvest, 2021). Hu et al. (2019) describes plant-based meats as a potentially "vital" means to reduce the risks of diabetes, cardiovascular disease, and some cancers. Others have focused on reducing the climate impact of food production and "the need to de-risk global food systems" (Zane Swanson et al., 2023). The private and public sectors have taken note as well; in 2022, the "plant-based meat, seafood, eggs, and dairy companies" foods industry attracted at least $1.2 billion in private investment activity and at least $874 million in public funding (The Good Food Institute, 2022, pp. 55, 85–88).

This enthusiasm has been propelled in some significant part by the informal hypothesis of price, taste, and convenience (henceforth, *PTC hypothesis*). Put succinctly by a leading non-profit in the space, the hypothesis proposes that plant-based meat "can compete on the basis of price, taste, and convenience, and just remove animals from the equation altogether" (Anderson, 2019). More specifically, the hypothesis first builds on the *PTC premise* that PTC are "what dictates consumer choice for just about everybody" (Anderson, 2019). Next, plant-based meats must have the same or better price, taste the same or better, and be as or more convenient compared to animal-based meat. According to the hypothesis, if plant-based meats were PTC-competitive to animal-based meats, then there would be no remaining reason for consumers not to abandon meat en masse.[2] Thus, just as cars replaced horses drawing carriages (Friedrich, 2020) and electricity replaced the slaughter of whales for oil used in lamps (Shapiro, 2018), it is supposed that plant-based meat would replace animal-based meat.

The PTC hypothesis has become pervasive in the discourse on plant-based meats, spreading beyond its origin within the farmed animal advocacy movement. As an informal hypothesis, the exact components are often modified, sometimes adding health or nutrition, subtracting convenience, or distinguishing between taste and texture. Major banks have weighed in, with Barclays declaring "taste and price will ultimately dictate whether or not alternative meat gains widespread acceptance" (Theurer et al., 2019, p. 3) and ING Group claiming "future growth" will depend on "the price gap," "better taste and nutritional profile," and "increase[d] distribution and availability" (Geijer, 2020). Boston Consulting Group advises companies to

[1] Also known variously as "cultured," "clean," "cell-based," "lab-grown," or "lab" meat.

[2] "When we're thinking about what it is that we want to eat, every single one of us thinks about the price of the food, we think about how it's going to taste. We may not be thinking about convenience but convenience is going to be a central factor. [...] We want to actually create plant-based alternatives and clean meat alternatives to conventional animal agriculture that compete on the basis of those factors and shift the world away from industrialized animal agriculture"(Cargill & Wiblin, 2018). "Despite rising awareness of the global impacts of our dietary choices, consumers continue to base their purchasing decisions primarily on price, taste, and convenience. Quite simply, reducing animal protein consumption is intractable for most people due to a lack of appetizing and affordable products that could serve as alternatives to conventional animal protein products. The challenge, then, is to innovate and bring to market diverse protein alternatives that are as delicious, price-competitive, and convenient as animal-derived food products are currently. By making healthy and sustainable alternative proteins comparable to conventional proteins in the areas of flavor, price, and ubiquity, alternative proteins become the default choice" (*GFI Research Program*, 2019, pp. 4–5). Other researchers offer similar descriptions of the PTC hypothesis (Anthis, 2018; Kankyoku, 2022).

"improve taste, texture, and price" and "remove perceived barriers (such as feeling that alternative meat products are difficult to cook)" (von Koeller et al., 2023). Similarly, other researchers and non-profits reiterate the view that consumer behavior around plant-based meats is primarily driven by PTC (Bryant, 2022; McHugh, 2022; ProVeg, n.d.). Finally, the popular press has adopted PTC as the key factors in analyzing plant-based meat (Graham, 2023; Splitter, 2020). In total, it is clear that PTC have been elevated as the key determinants of the impact of plant-based meat.

While the PTC hypothesis is widespread, it has received little scientific scrutiny. We fill this gap here by aiming to evaluate whether a large majority of present-day consumers would be expected to switch from animal- to plant-based meat if it were PTC-competitive. In doing so, we necessarily discuss possible operationalizations of PTC and evaluate the premise that PTC are the main determinants of food choice. In parallel, we review the nascent empirical literature addressing the effects of each factor individually before reviewing studies that test all three factors in conjunction. Important limitations of the reviewed literature will also be discussed before concluding with an overall assessment of the PTC hypothesis and recommendations.

The PTC premise

Before examining the PTC hypothesis in full, we will examine the evidence supporting the key motivating premise that PTC are the primary determinants of food choice. Of course, there is no dispute that PTC are *important* factors in people's food choices, but research in food psychology demonstrates these are not the sole or primary factors. Intuitively, this fact is apparent when considering basic consumer behavior: any given grocery store likely offers thousands of cheap, tasty, and convenient products, and yet, consumers decide to purchase only some of these products, without gathering any information on the large majority of them. Presumably, consumers do so by relying on factors well beyond PTC. Indeed, the psychological literature has identified myriad influences of food choice spanning psychological, biological, physiological, situational, and socio-cultural factors in addition to product characteristics (Köster, 2009). Furthermore, a rich literature on the psychology of meat consumption has identified factors particular to the consumption of meat and animal products. For example, people feel a peculiar personal attachment to meat (Graça et al., 2015), believe that meat is necessary for health, feel that meat consumption is socially normative, and perceive meat as a nice and natural component of a healthy diet (Piazza et al., 2015).

Indeed, the notion that PTC are the primary causes of food choice does not arise from the academic literature but seems to have been popularized in a paper by a non-profit promoting the PTC hypothesis, which argues "[t]he three foundational motivations for food choice are taste, cost, and convenience" (Szejda et al., 2020, p. 5). The report reviews three studies to support the primacy of PTC. However, none of these studies finds PTC to be the top three factors in determining food choice. All are cross-sectional surveys of adults in the United States (US) and ask participants to rate the impact or importance of four to seven factors on their food purchasing decisions. Rankings were then determined based on the average of the responses. The first study was conducted in 1998 and found, in descending order of importance: taste, cost, nutrition, convenience, and weight control (Glanz et al., 1998, p. 1122). The second survey was administered annually from 2007 to 2010 and found, in descending order of importance: taste, nutrition, cost, and ease of preparation (convenience) (Aggarwal et al., 2016, p. 14). Finally, the third survey was performed annually from 2012 to 2019 and consistently found, in descending order of impact: taste, price, healthfulness, convenience, and environmental sustainability (*2019 Food & Health Survey*, 2019, p. 12). In 2019, the same survey added two additional factors: "your trust in the brand," which ranked second below taste, and "recognizing the ingredients that go into the product," which ranked fourth after price (*2019 Food & Health Survey*, 2019, p. 13). While these three surveys are the most frequently cited in support of the PTC hypothesis, there are others; however, they generally share the same methodological limitations.

First, as the authors of the original report acknowledge, these surveys are "best-suited for understanding attitudes rather than for perfectly predicting behavior," and future research should "focus on studies of actual behavior rather than self-reported behavior" (Szejda et al., 2020, pp. 7, 11). Thus, critically, the

rankings in these studies reflect what people *perceive* as the most important factors rather than what would *actually* cause them to change their diets. Second, the cited studies were designed primarily to investigate the role of a few particular factors in food choice rather than to identify the most important factors. For example, one abstract indicates the study's objective is "to examine the self-reported importance of taste, nutrition, cost, convenience, and weight control on personal dietary choices" (Glanz et al., 1998, p. 1118). This explains why the studies examine only a handful of factors rather than the myriad influences of food choice. Third is a relatively minor issue, but these studies analyze the average ranking of each factor rather than how individual consumers rank the factors. Interpreting these averages as the preferences of individuals invokes the ecological fallacy: even if PTC were the most important factors on average, this does not imply that individual participants would each rank PTC as most important. In summary, there is little compelling evidence to nominate PTC as the primary causes or drivers of food choice.

Producing compelling evidence to substantiate just the premise of the PTC hypothesis would require an ambitious experimental effort. Before addressing each of the above three methodological issues, the hypothesis would need to be properly operationalized. The aforementioned surveys leave the meaning of PTC open to interpretation. For example, respondents might interpret convenience to mean either "easy to prepare" or "readily available." Taste might capture a wide array of concepts from flavor to texture or, in a different sense, personal aesthetic preference. Therefore, each factor must be carefully operationalized into specific empirical measurements. Next, to strongly support the hypothesis, factors must be tested experimentally rather than relying on merely asking people to report what they find most important since these self-reports are likely unreliable. To identify the *most* important determinants of food choice, it is necessary to contrast the many different potential causes and their combinations: appearance, odor, health, sustainability, social norms, familiarity, food safety, religion, and so on. Finally, there is the challenge of defining the "most important" set of factors for any given consumer, which becomes more difficult when testing numerous factors. For example, for some consumers, an allergy or religious belief might dominate all other factors in their food choices. Of course, this varies by food: allergies are quite important in choices about peanut products but less relevant for black beans. Which set of factors are reasonably deemed most important then depends on both the individual and the product in question.

Operationalizing and testing PTC individually

Given the lack of experiments systematically testing PTC in general as determinants of food choice, we will instead initially focus on each factor individually. In the context of choosing between plant- and animal-based meat, we will operationalize and review empirical evidence in turn for each factor. While this approach does not directly test the PTC hypothesis, which requires that competitiveness be obtained for all three factors in conjunction, it allows a larger body of evidence to be adduced. Furthermore, it seems reasonable to posit that a marginal improvement in any one factor, thus approaching but not necessarily obtaining PTC-competitiveness, might still result in some of the hypothesized reduction in animal-based meat usage.

Price

Price is the most clearly defined component of the PTC hypothesis, referring to the differential in retail prices for a pair of animal- and plant-based meats. Price might also seem to have the most straightforward case in its favor: decreases in plant-based meat prices presumably lead to more sales and, ultimately, less animal-based meat sales. However, this hypothesis is not guaranteed. For example, a lower price may lead some consumers to treat plant-based meats as inferior goods—or cheap substitutes—rather than a better deal. This effect might contribute to the lower popularity of margarine, which was designed as a substitute for butter at the time of its development in the 1880s (Dupré, 1999). Alternatively, consumers simply may not treat the two products as substitutes. Whatever the reason, the extent of price substitution behavior can be measured via cross-price elasticity of demand estimates emerging in the economics literature. Our research has reviewed estimates of cross-price elasticities between margarine and butter (Mendez et al., 2023) and plant-based and dairy milk (Mendez & Peacock, 2021). The results suggest that behavior might be

inconsistent across studies. Many estimates suggest that decreased margarine or plant-based milk prices result in *increased* consumption of the corresponding animal product (known as complementarity, the opposite of substitution). While the studies we reviewed had important methodological limitations, this evidence casts doubt on the general notion of price substitution between plant-based analog products and their animal-based counterparts.

The two existing cross-price elasticity studies of plant-based meat sold in US grocery stores are consistently inconsistent. (A third study is forthcoming (Hirsch, 2022).) Zhao et al. (2022) found that plant-based meat (75% of which was the beef-like Impossible and Beyond Meat brands) acts as a complement for beef (cross-price elasticity −0.003) and pork (−0.003) and a substitute for chicken (0.008), with each elasticity reaching statistical significance at the 1% level. Meanwhile, Tonsor & Bina (2023) found basically the opposite, with plant-based meat acting as a substitute for beef (0.01) and pork (0.11) but a complement for chicken (−0.04), with all but beef reaching statistical significance at the 5% level. The two studies are not perfectly comparable and have certain methodological limitations, but they do agree that any effects of changes in plant-based meat prices seem to have only very small effects on animal-based meat sales. Note that some earlier estimates of plant-based meat cross-price elasticities use different study designs and analyses that constrain cross-price elasticities to substitution (examples reviewed in Lusk et al. (2022) Supplementary Table 5). Since study designs like discrete choice experiments are often analyzed so as to assume products are substitutes (Caputo & Scarpa, 2022, p. 82), estimates from these studies should not then be taken as evidence against complementarity. While new methods relax this assumption, the results are again inconsistent, finding substitution for the Beyond Burger with beef and chicken but complementarity for the Impossible Burger (Tonsor et al., 2022, Table 7). Thus, while price is well-defined, its role in helping plant-based meats displace animal-based meats is not.

Taste

Taste here means the gustatory perception of flavor via the tongue and mouth rather than the aesthetic or preferential meaning of the word. While further operationalization of taste competitiveness is not usually explicated, product pairs meeting the criteria are described as "the exact same product" and "indistinguishable" (McKenzie, 2022). This description has been understood to mean the products will pass a blinded taste test of some sort (Stevens, 2021). For example, one classic design would give each blinded taster a sample of plant- and animal-based meat and ask them to correctly classify which was which. If half or less of the participants can classify them correctly, the test is passed, and the products are equivalent! However, this operationalization does not capture the idea of tasting the same *or better*; the results only show whether or not the two products were indistinguishable. Further note that this operationalization includes assumptions about other characteristics of the products besides taste: the products must also have identical texture, smell, shape, etc., to pass. These characteristics fall outside most people's conception of "taste" and thus are not likely captured by the survey evidence intended to support the PTC premise.

However, more importantly, blind taste tests may lack external validity, as, outside an experimental setting, plant-based meat consumers will never be blinded. Instead, consumers will be informed of what it is they are eating, as is necessitated by food labeling laws, allergies, dietary restrictions, and ethical norms. Informed taste tests further probe the question of how to operationalize the concept of "taste competitiveness," as one can no longer meaningfully use participants' ability to classify plant- and animal-based meats as an outcome measure. Instead, one might ask how similar an animal and plant-based product taste, which product tastes better, or to rate each product's taste on a Likert scale.

Regardless of how exactly taste is operationalized, for these distinctions to matter, blind and informed taste test results must substantively differ. Indeed, this possibility is generally recognized (Garber et al., 2003) as taste is understood to be determined only partly by the *contents* of food; consumer psychology, context, and environment are also important causes of taste perception (Krishna & Elder, 2021). Research on plant-based meats so far has not focused specifically on contrasting taste perception in blinded and informed conditions. However, the available evidence generally finds modest but meaningful effects on related measures of consumer

acceptance, although some studies are small and potentially underpowered.

In Sogari et al. (2023), 175 American consumers were randomized to blind and informed conditions, tasted four burgers (Beyond Burger, called "pea protein"; Impossible Burger, called "animal-like protein"; "hybrid meat-mushroom" burger; and "100% beef" burger), and then ranked their preference for each burger. Informing participants of the burgers' identities (for example, "pea protein burger") caused a statistically significant drop in the Beyond Burger's rank from third to fourth most liked, while the Impossible Burger remained first. In Caputo et al. (2022), 86 American consumers were randomized to blind and informed conditions, tasted four burgers (Beyond, Impossible, hybrid meat-mushroom, and 100% beef burger), and then participated in an experiment to measure willingness-to-pay for the burgers. Differences in willingness-to-pay between conditions did not reach significance given the small sample size; however, the point estimates suggest information caused willingness-to-pay to *increase* for the Impossible Burger by \$0.91 and *decrease* for the Beyond Burger by \$0.22 and the beef burger by \$0.77. In Martin et al. (2021), 102 French consumers sampled both an animal- and plant-based sausage, first blinded and then with packaging information, and marked the strength of their preference on a scale ranging from animal-based (−10) to plant-based (10). After seeing the packaging, a statistically significant shift in preferences in favor of the plant-based sausage was detected (from −6.2 to −4.3), although consumers still strongly preferred the animal-based sausage. Finally, in Schouteten et al. (2016), 53 consumers sampled both an animal- and plant-based burger, first blinded and then with packaging information. In contrast to the previous results, a meaningful effect of information was not detected, with average overall liking on a 9-point scale increasing by 0.2 from 4.7 for a plant-based burger and increasing by 0.2 from 6.5 for an animal-based burger. Note that this plant-based burger was slightly disliked, and the confidence intervals for these effects would be wide.

Given these results, even plant- and animal-based meats which are indistinguishable in a blind taste test might still be experienced differently in an informed test. While the idea that plant-based meats must pass a blind taste test to be taste-competitive is intuitively appealing, informed tests have the benefit of reflecting consumers' naturalistic experience of purchasing plant-based meats. However, ultimately determining which approach identifies plant-based meats that are most effective in displacing animal-based meat is an empirical question largely lacking direct evidence. What evidence we do have suggests that tasting identical to meat may be less important than posited by the PTC hypothesis. Michel et al. (2021) surveyed 1,039 German consumers on whether "meat alternatives should taste identical to meat (0) or not at all like meat (100)." The mean response of 46 and standard deviation of 33 suggests a large degree of ambivalence, although this self-report should be regarded critically. A study of 93 Dutch meat consumers found wide differences in participants' perception of plant-based meat's similarity to animal-based meats but found little resulting association with subsequent liking of dishes incorporating that plant-based meat (Elzerman et al., 2011, p. 239). This is, to some extent, good news: perhaps plant-based meats may not need to perfectly emulate animal-based meat in order to compete, but only to be tasty in their own right.

Convenience

Convenience tends to be the least elaborated factor and has been discussed less in recent years. It is also the broadest in its possible interpretations, potentially applying to every step of obtaining and consuming food. Convenience might be considered in two parts: availability and functionality. Competitive availability would then entail plant-based meat needing to be available everywhere animal-based meat is sold. Furthermore, purchase must be as or more convenient; for example, products must be available on the same menu or in the same part of the store (rather than a separate menu or aisle). Competitive functionality might include as or more functional packaging, similar (or lower) levels of perishability, and preparation that requires the same or less effort and time. Plant-based meat might need to be as or more functionally flexible in forming different end products, like how beef can be used whole or ground. Finally, convenience might be interpreted as individuals' knowledge and skills for obtaining and preparing plant-based meat.

Unlike price or taste, the availability component of convenience is not an attribute of the product itself but its ubiquity and physical surroundings. Thus, while scenarios invoking competitiveness on price and taste

require only imagining a superior product, convenience-competitiveness could require an effective doubling of the animal-based meat supply chain. Of course, ideally, the displacement of animal-based meat would lessen the burden, but this nonetheless could represent a much larger change to the world than price or taste competitiveness. Given the breadth of feasible operationalizations of convenience, no empirical work has probed convenience-competitiveness generally. Some work has focused on availability within grocery stores, moving plant-based meats to the (animal-based) meat aisle from devoted 'vegan' aisles. A non-randomized study of 108 grocery stores found the move increased sales of plant-based meat but did not decrease sales of animal-based meat (Piernas et al., 2021). Another smaller non-randomized study of nine stores found a very small increase in plant-based meat sales and no evidence of an effect on animal-based meat sales (Vandenbroele et al., 2019). In summary, there is a lack of clarity on what exactly constitutes convenience equivalence, and what little evidence might be relevant does not find a meaningful impact of increased convenience on animal-based meat usage.

Empirical tests of the PTC hypothesis

Thus far, neither a strong motivation for the premise that PTC largely determine food choice nor evidence in favor of the impact of PTC individually have been found. However, this is not sufficient to reject the PTC hypothesis, which holds that if plant-based meat is PTC-competitive with animal-based meat, the large majority of current consumers will shift from animal- to plant-based. To test the PTC hypothesis directly, we will focus narrowly on studies where participants choose between an animal-based meat and a putatively PTC-competitive plant-based meat. This approach aims to test the implication of the PTC hypothesis that closely similar plant- and animal-based meats will serve as substitutes.

However, it is crucial to note that these narrow outcome measurements focused only on the choice between target products do not accurately capture the impact of plant-based meats. A counterfactual scenario must be considered to understand the full impact of plant-based meats: what would have happened in the absence of a plant-based meat? For example, suppose a study found that 25% of consumers order a plant-based rather than animal-based burger. A naive interpretation of this result is that the availability of a plant-based burger causes a 25% reduction in animal-based burgers. However, the result could, in fact, represent no effect at all if, given the option, those consumers would not have purchased an animal-based burger anyway. Instead, they may have chosen a different plant-based meal or purchased nothing at all. We will revisit this issue later to illustrate how it can significantly alter estimates of impact.

Hypothetical discrete choice experiments

Hypothetical discrete choice experiments (HDCEs) provide some relatively weak tests of the PTC hypothesis. HDCEs generally ask consumers to imagine hypothetically picking a plant- or animal-based burger from a menu. The menu usually includes randomly selected prices, which are then analyzed to produce estimates of selection rates when prices are equal. Participants are often told that the burgers taste the same or similar, and they are presented as if they are prepared and ready to eat. Thus, at least in a hypothetical setting, these studies obtain PTC-competitiveness.

One such study offered US consumers two plant-based, one animal-based, and one cultivated meat (labeled "lab-grown") burger. The results suggested that about 19% of consumers might purchase an equally priced plant-based or cultivated meat burger instead of an animal-based burger, with 10% making no purchase (Van Loo et al., 2020, fig. 3A).[3] An otherwise identical version of the experiment provided respondents with assurances that the "plant-based burger patty [...] mimics the taste of an animal meat burger" and information about the production process of the different burgers (Van Loo et al., 2020, fig. 2). Together, this information increased purchases of plant-based or cultivated meat to 27%, with 8% making no purchase (Van Loo et al., 2020, fig. 3A). A second study indicated that "all burgers taste the same" and found that 70% of a Canadian sample would purchase the beef burger, 25% the plant-based burger, and 5% would make

[3]This figure is likely an overestimate (in favor of the PTC hypothesis) since it also includes the cultivated meat burger.

no purchase when prices were equal (Slade, 2018, Table 5). However, when asked, only 8% of respondents believed all the burgers would taste the same. The author notes that "to some extent, this is representative of the actual choice environment—even if burgers did taste equivalent, many consumers may not believe this to be the case" (Slade, 2018, p. 431). A third study compared a "Beef Burger" and "Beyond Meat Burger" without any indication of taste equivalence. At equal price, 22% of US grocery shoppers (excluding participants who would opt to buy neither) would select the Beyond Burger (Tonsor et al., 2021, fig. 20; Tonsor et al., 2022, p. 5). A fourth study compared "plant-based meat-like burgers" and conventional hamburgers at equal prices after providing participants with information about both, including that the plant-based meat was "very meat-like in terms of texture, color and taste" (Carlsson et al., 2022, p. 24). Only 11% of Swedish hamburger consumers selected the plant-based meat option (Carlsson et al., 2022, Table 2).

Although not precisely an HDCE, a series of surveys asked a similar question: whether participants preferred "real meat from animals" or "meat-like alternatives made from plants," without reference to specific products or the option not to purchase (Miller, 2021). Conducted in June 2020 across 27 countries, 27,000 meat-eating participants were told to assume plant-based meat and animal-based meat "tasted equally good, had equal nutritional value and cost the same." 41% of the total sample preferred plant-based meat; a slight majority (51–55%) in five of the countries preferred plant-based meat, 63% in Mexico, and 66% in Vietnam. However, the design of this study likely increases these estimates: the addition of "equal nutritional value" likely increases the attractiveness of the plant-based meat; the environmental framing and questions used earlier in the survey might increase social desirability bias; using a text description rather than pictures of the possible items and broad non-specific question wording might elicit more hypothetical bias; and participants are forced to choose one or the other of animal-based meat or plant-based meat. That said, the study included only self-identified meat eaters, which would generally push the estimates towards animal-based meats, as might excluding assurances of competitive convenience. Indeed, estimates from Miller (2021) tended to be higher than estimates from other studies (Figure 1), although the comparisons are imperfect. For example, Carlsson et al. (2022) found 11% of Swedes preferred plant-based meat, while Miller (2021) found 45%. In summary, the results of HDCEs conflict with the hypothesis that consumers largely prefer PTC-competitive plant-based meats over animal-based meat.

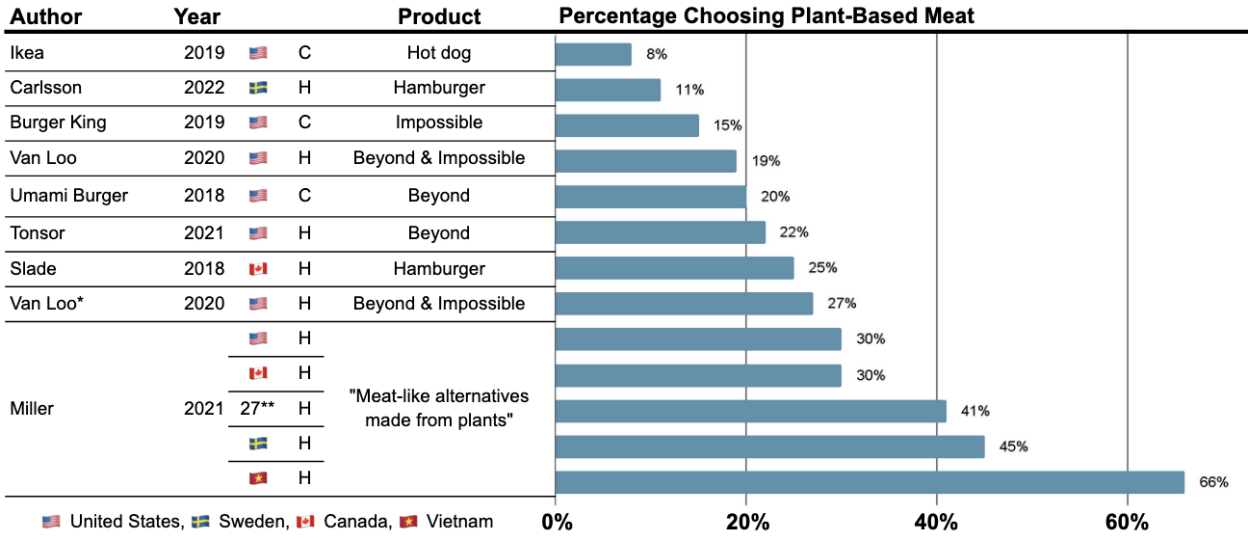

Figure 1: Percentage of participants choosing plant-based meat instead of animal-based meat during either an HDCE (denoted "H") or a commercial case study ("C"). Error bars are not included, as no studies reported standard errors. Flags denote the country in which participants were recruited. Supporting data available at https://osf.io/5cqem/. *Second Van Loo et al. (2020) study with additional information. **Average across 27 countries.

Commercial case studies

Of course, the results of HDCEs may not translate to actual behavior. Hypothetical choice and self-reports of diet change likely tend to exaggerate the extent of meat reduction: one comparison found that in a hypothetical choice, 59% of meals selected were meat-free, while in actuality, sales data found only 36% of meals to be meat-free (Brachem et al., 2019, p. 22). For data on actual behavior, we can look at the introduction of plant-based meats in commercial contexts, although price details are not always available. Furthermore, unlike the previous HDCEs, which often rely on representative samples of the population, these commercial case studies necessarily include only customers who self-selected to make a purchase at that particular restaurant. Thus, these estimates may still be somewhat optimistic.

To start, the home-goods-retailer-cum-cafeteria Ikea sells plant-based hotdogs that are equally or lower-priced, readily available alongside animal-based hot dogs, and "received a 95 percent approval rating" in taste testing in Sweden (Webber, 2019). In September 2019, Ikea's plant-based hot dogs composed about 8% of annual hot dog sales globally (Southey, 2019).[4] Similarly, a sample of 350 locations of the fast-food chain Burger King indicates that Impossible Burgers represent about 15% of total burger sales,[5] and the sales of beef burgers "had not fallen as a result" (Mehta & Balu, 2019). However, the Impossible Burger was generally slightly more expensive and may sometimes take longer to prepare than the beef burger, which could be especially important to fast food customers. In terms of taste, Sogari et al. (2023) found the Impossible Burger's mean preference ranking in a blind taste test was not statistically significantly different than a beef burger (2.1 vs 2.5, respectively, indicating both burgers ranked around second on average). That said, the beef burger may have been significantly less salty than the Impossible Burger, potentially lowering the bar for taste equivalence. Another blind taste test found that the Impossible burger patty had a similar average liking score to a beef burger (*Chicken and Burger Alternatives*, 2018).[6] Moreover, complete meals containing plant-based meats tend to be somewhat better liked than plant-based meats on their own (Hoek et al., 2012, Table 6; Qammar et al., 2010, p. 554), although this trend may not be universal (Elzerman et al., 2011, fig. 2). As such, taste competitiveness or near competitiveness is likely a reasonable assumption about prepared Impossible burgers but does remain an unanswered empirical question. As a final example, the burger restaurant chain Umami Burger introduced the Impossible Burger in 2018; in the six weeks following, it represented ~20% of burger sales (Cameron & O'Neill, 2019, fig. 17). These case studies again suggest that most consumers do not prefer plant-based meats, even for relatively PTC-competitive products.

Malan 2022 field experiment

The strongest evidence of actual behavioral impacts of PTC-equivalent plant-based meats likely comes from a study introducing Impossible Foods' plant-based ground beef to a University of California Los Angeles dining hall (Malan et al., 2022). Impossible ground beef was introduced at two stations in the dining hall. On Thursdays, students had the option of receiving prepared burritos with either Impossible ground beef, animal-based steak, or veggies, while the build-your-own entree line offered Impossible ground beef every day alongside animal-based ground beef.

In this study, price is entirely equivalent since students pay for dining hall access for the entire semester, not individual meals. With regards to taste, Impossible ground beef specifically has not been subjected to any public taste tests. However, as reviewed above, the Impossible Burger, which is made of similar ingredients, has been found to taste equivalent in some studies. The study does not describe exactly the form of the beef in the steak burrito, making its taste equivalence less certain but probably still a reasonable inference. For the ground beef served on the build-your-own entree line, taste equivalence seems very likely. We can further surmise that the Impossible ground beef meals in the study were at least desirable: a follow-up survey found that 71% of purchasers were repeat purchasers (Malan, 2020, p. 189). Convenience is likely equivalent as

[4] 8% = 10,000,000 veggie dogs / (10,000,000 veggie dogs + 110,000,000 conventional dogs)

[5] The source indicates 230 "signature beef Whoppers" were sold daily. It is unclear whether this figure includes, for example, the "Double Whopper." With 40 Impossible Whoppers sold daily, the percentage is calculated as 15% = 40 / (230 + 40).

[6] Burger identity was provided in personal correspondence with the author, David Meyer (2023).

well since the burritos are prepared for students by dining hall staff, and the build-your-own entree line is self-serve for both animal- and plant-based ground beef.

The study measured how many beef-containing meals were distributed at the intervention dining hall, where the Impossible ground beef was available, as well as distribution at two other dining halls as controls, which we refer to as A and B. For all dining halls, data on how many meals of each type were served was available before and after the intervention. Dining halls were not randomized to intervention and control status, and participants were free to cross over between dining halls during the study, both factors that could bias effects in either direction. Control dining hall A was adjacent to the intervention dining hall, so intervention materials were potentially visible, while control dining hall B was isolated from the intervention. In addition to making plant-based meat available, the study employed several co-interventions designed to reduce meat consumption (Malan, 2020). These included environmental education, low carbon footprint labels on menus, and an advertising campaign to promote the new product, all of which have some evidence demonstrating their effectiveness (Bianchi, Dorsel, et al., 2018, p. 11; Brunner et al., 2018; Jalil et al., 2019; Osman & Thornton, 2019). Thus, the study's results cannot be entirely attributed to the addition of plant-based meat options to the intervention dining hall's menu.

To begin, we focus only on the burrito station of the intervention dining hall. In the ten weeks after adding the Impossible burrito to the intervention dining hall's menu, 26% of burrito purchasers chose the Impossible, 7% the veggie, and the remaining 67% the steak burrito (Malan, 2020, Table 12). Consistent with previous results, in a scenario that ensures price, convenience, and potentially taste competitiveness, the portion of consumers selecting the plant-based meat option remains modest.

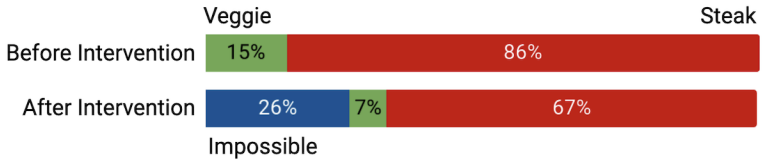

Figure 2: Percentage of each burrito type selected before and after intervention.

The before and after, as well as control, data available in this study also demonstrate crucial shortcomings in the HDCEs and commercial case studies: they do not compare against a counterfactual where plant-based meat is unavailable. Thus, it is unclear what would have happened otherwise, which is crucial for understanding the causal effect of plant-based meat on animal-based meat usage. One approach to estimate the outcome of such a counterfactual scenario is to use the before-intervention data in Figure 2, which shows the veggie burrito comprises 15% of selections in the absence of the Impossible burrito. With the Impossible burrito available, this share declines to 7%, suggesting the Impossible burrito partially replaced the demand for veggie burritos rather than animal-based beef. Thus while 26% of burritos distributed were Impossible burritos, using the before-intervention data suggests only a 19 percentage point decline in steak burritos.

The control dining halls in the study provide a more rigorous approach to estimating a counterfactual than the before and after analysis. However, to make the control and intervention dining halls comparable, we must expand our focus to all Impossible ground beef meals, not just burritos. Since Impossible ground beef is designed to be a substitute for animal-based beef, we expand our analysis to all animal-based beef meals (rather than just steak burritos) but exclude impacts on other meats like poultry or pork. For comparison's sake, we can repeat the analysis in Figure 2 using this new outcome measure (Figure 3). As before, we first consider a naive analysis that assumes every Impossible ground beef entree displaced an animal-based beef entree. Since 11.4% of entrees in the intervention dining hall were Impossible ground beef, we would assert an 11.4 percentage point reduction in beef entrees. Next, we look at actual beef demand before and after adding Impossible ground beef to the intervention dining hall and find a much smaller decline of 3.3 percentage points.

To compare the intervention and control dining halls, we will compute a difference in differences. That is,

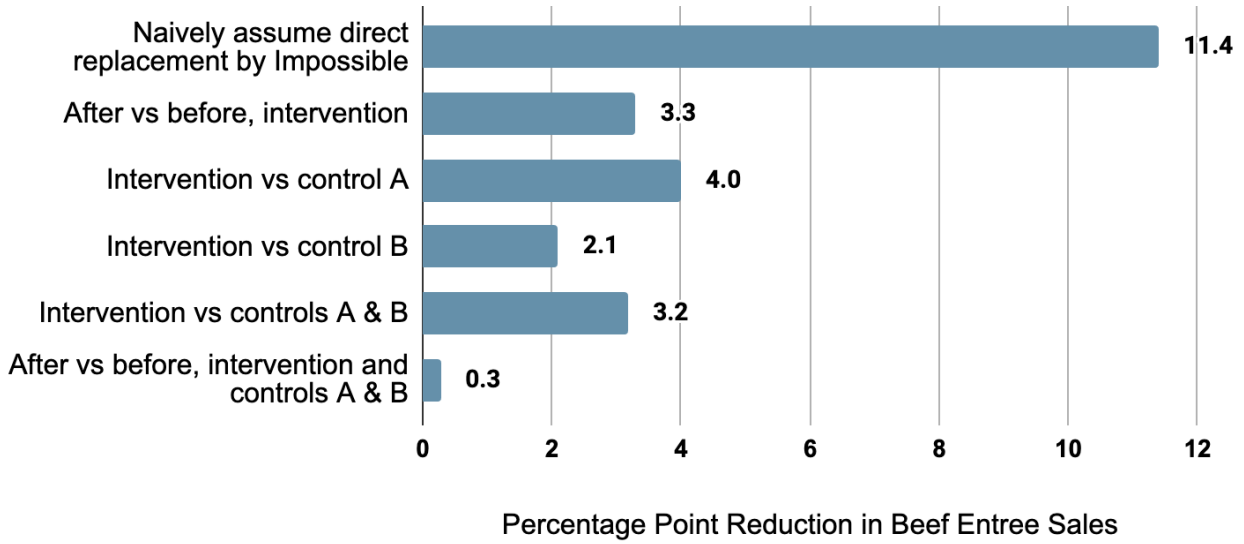

Figure 3: Six different analytic approaches to calculating the effect of adding Impossible ground beef to the menu, among other interventions, on demand for beef entrees. Supporting data and calculations are available at https://osf.io/5cqem/.

we will first compute changes in the proportion of beef entrees distributed before and after intervention in each dining hall. Second, we take the difference of the before-and-after changes between the intervention and control dining halls.[7] When comparing the intervention dining hall against control dining hall A—where the percentage of beef entrees actually *increased*—the effect of Impossible ground beef looks somewhat better, resulting in a 4.0 percentage point decrease in beef entrees. Conversely, beef demand went down in control dining hall B, so the estimated effect of Impossible ground beef looks somewhat smaller at 2.1 percentage points. Lastly, comparison to both control sites combined yields an effect in between the others, a 3.2 percentage point decline. While these are small numbers, the *relative* effect of different approaches to estimating a counterfactual is large, which underscores the importance of appropriately measuring what would have happened otherwise.

Nonetheless, this variation in the control dining halls is surprising: after all, in the absence of intervention, we might expect no change. In this case, the prominent launch of Impossible ground beef at the intervention dining hall may have affected which of the three dining halls the students chose. Looking at the change in the number of entrees distributed at each dining hall suggests one possible story of spillover. Control dining hall A, which was adjacent to the intervention dining hall, saw a 12,432 entree decline in overall meals distributed, a 2.4 percentage point decline in demand for other vegetarian options (besides Impossible ground beef), and a 0.7 percentage point increase in beef entree demand. Meanwhile, the intervention dining hall saw a 16,529 meal increase. Together this points to the possibility that the intervention, in fact, concentrated students likely to eat Impossible ground beef at the intervention dining hall while encouraging beef-eating students to go next door, without having much effect on total consumption. Control dining hall B, which was further away, also saw an 8,775 entree decline in the overall number of meals distributed. However, this control saw a small increase (1.1 percentage points) in demand for other vegetarian options and a small decrease (1.2) in beef demand, opposite of the changes at control dining hall A.

One way to account for this potential spillover of students between intervention and control is to simply ignore the distinction between intervention and control sites. Instead, the study sites can be combined in a single before and after analysis. This yields a very small change in beef entree selection, only 0.3 percentage

[7] For example, $(\text{Intervention}_{\text{After}} - \text{Intervention}_{\text{Before}}) - (\text{Control}_{\text{After}} - \text{Control}_{\text{Before}})$.

points, compared to a 5.0 percentage point increase in Impossible ground beef entree selection. There was also a 2.6 percentage point decline in other vegetarian selections. This analysis supports the idea that introducing Impossible ground beef may have primarily attracted students already willing to eat vegetarian entrees from other dining halls. While Malan (2020) is not straightforward to interpret, it illustrates the importance of making comparisons to counterfactual scenarios and demonstrates that only a small share of consumers might prefer PTC-competitive plant-based meat.

Further caveats

In reflecting on the evidence considered here—from commercial case studies to controlled experiments—we should consider several caveats that may make these early estimates of the impact of plant-based meats overly optimistic. First, all the eateries in these studies ultimately choose to provide plant-based meats and are thus potentially subject to selection bias in favor of eateries with customers likely to enjoy plant-based meats. For example, Malan et al. (2022) was conducted with college students, who are usually under the age of 35, and at the University of California, Los Angeles in the western US, both demographics which are more likely than average to select plant-based meats in HDCEs (Tonsor et al., 2022, Table 1). Second, many, if not most, of the reviewed studies likely included numerous and sometimes extensive additional co-interventions also designed to increase sales of plant-based meat and/or decrease sales of animal-based meat, like promotions, ad campaigns, and environmental information. These will presumably reduce in intensity over time, as might their effects.

Third, these early studies may represent novelty effects and tap into consumers' curiosity to try something new. One survey identified "I like to try new foods" and "I've been hearing a lot about them and was curious" as the two most popular factors in a self-report of why customers tried plant-based meats (*A Consumer Survey on Plant Alternatives to Animal Meat*, 2020, p. 5). This effect would also be expected to fade over time. Indeed, this decline may already have been observed. In 2019, sales of the Beyond Taco at the fast-food chain Del Taco declined from 6% to 4% of the sales mix (Maze, 2019), and across two samples of Burger King stores, sales of the Impossible Burger declined from 30 per day per store to 20, and from 32 to 28, in the weeks following introduction (Shanker & Patton, 2020).

Fourth, effects could be reduced by spillover, where an intervention has an impact outside the expected context. Plant-based meats may affect the consumption of animal products besides the one they are intended to emulate or affect subsequent food choices. Mechanistically, spillover can occur in individuals or institutions. For example, moral licensing could occur, with an individual consumer's virtuous plant-based eating at lunch resulting in feeling entitled to indulge in more meat for dinner. A lack of satiation could also lead to spillover: an unsatisfying plant-based meal might leave the consumer craving animal products. Positive spillover could also occur, with a tasty plant-based meal inspiring further plant-based consumption. As an example of institutional spillover, a university dining hall might add a plant-based burger to the menu on Mondays but simply serve animal-based burgers on Tuesdays and displace another vegetarian option.

However, the extent to which spillover occurs is an empirical question. One study of the cross-price elasticity of plant-based meats already suggests spillover. In Zhao et al. (2022), at least 75% of the plant-based meat in the study was beef-like, but the study found unexpected complementarity for beef and substitution for chicken instead. Another study measured spillover effects of increasing the availability of vegetarian options at lunch on consumption at the subsequent dinner. There was little evidence for spillover, but the estimate was relatively uncertain (Garnett et al., 2019, Supplementary Table S21).[8] Detecting spillover effects requires comprehensive measurement of relevant outcomes; in this case, animal product usage both at the time and location of intervention, but also usage afterward and elsewhere. Without such careful measurements, the size and direction of spillover effects, and thus the total impact of plant-based meats, will remain uncertain.

Fifth, the body of research reviewed here is subject to publication bias, whereby we are likely more aware of results perceived as positive rather than negative. For example, companies are less likely to highlight

[8]The 95% confidence interval for the odds ratio was [0.795, 1.141], with a point estimate of 0.953.

failed product launches, and academics are less likely to publish results that do not find an effect. Sixth, the body of literature largely lacked pre-registration and analysis plans and thus is vulnerable to reporting bias, where authors selectively report favorable results. That said, for some studies, it's unclear which direction would be "favorable." For example, some authors were funded by the animal agriculture industry, and an incentive could conceivably exist to either exaggerate or minimize the impact of plant-based meats. In any event, there was no direct evidence of reporting or publication bias. In total, these six caveats suggest the reviewed studies might be optimistic yet.

Conclusions & recommendations

Collectively, these results show that the PTC hypothesis, in its current form, is likely false. The underlying premise of PTC as key determinants of food choice is not supported by evidence from cross-sectional surveys on consumers' self-reported determinants. The little available evidence thus far suggests PTC do not individually significantly reduce animal-based meat usage. HDCEs find that a minority of consumers select PTC-competitive plant-based meats instead of animal-based meats. (Miller (2021) adduces two countries where plant-based meat selection nears two-thirds when health equivalence is also assured. However, the study design is especially subject to hypothetical and social desirability biases and likely yields estimates that unrealistically favor plant-based meats.) Data from introducing plant-based meats at particular restaurants suggests that they draw only a modest portion of customers. Finally, a controlled experiment introducing high-quality plant-based meat to a dining hall—at equal price and convenience to animal-based meat—shows that most participants did not choose plant-based meat. Across six lines of evidence, it is clear that the empirical evidence opposes the PTC hypothesis.

This result does not imply that plant-based meats have no role in animal, environmental or public health advocacy. Instead, new, evidence-based theories of change about the role of plant-based meats must be advanced and rigorously evaluated rather than simply assuming that creating and selling PTC-competitive plant-based meats will result in the widespread displacement of animal-based meat. Important alternatives to the PTC hypothesis might consider the role of future consumers rather than present-day consumers, who have been the focus of this paper. Future consumers might experience a large change in social norms or otherwise shift their preferences toward consuming plant-based rather than animal-based meats. This is a common feature of many animal advocacy theories of change (Delon et al., 2022), and advocates will potentially find it difficult to shift social norms in favor of plant-based meat.

Next, a more expansive notion of taste should be considered rather than a narrow focus on developing products that taste identical to animal-based meat. Of course, plant-based meats need to taste *good* to gain consumer acceptance, but there is little evidence that tasting identical to animal-based meat is essential. Furthermore, meat is not a monolith but a wide target with diverse taste profiles. This provides an opportunity to produce plant-based meat that tastes as "good as *a* meat" rather than "the same as meat." Generally, more taste tests of plant-based meats would be beneficial. Given the $7.8 billion in investments in plant-based food companies (The Good Food Institute, 2023, p. 55) and calls for further large-scale government research and development funding (Friedrich & Purvis, 2022), additional funding might reach diminishing marginal returns in improving taste. Without appropriate baseline taste tests, it will be impossible to determine if improvements were realized.

Given the scale and breadth of investment—spanning non-profits; for-profits; and, increasingly, governments—the sparsity of research evaluating the effectiveness of plant-based meats in serving their stated goal of reducing animal-based meat usage is notable. While this review focused only on work relevant to the PTC hypothesis, recent systematic reviews reveal only a handful of additional studies testing the effect of plant-based meats on animal-based meat usage (Bianchi, Garnett, et al., 2018; Grundy et al., 2022; Taufik et al., 2019). Few resources are currently devoted to the scientific testing of *any* theories of change involving plant-based meats, let alone the PTC hypothesis. What research exists has not been a focus of discussion among advocates. It is crucial, then, that future research empirically evaluates the effects of plant-based

meats on the displacement of animal-based meat and compares these effects with those of other interventions to reduce animal-based meat usage. Furthermore, advocates must engage with this work and adjust their strategies accordingly. Ultimately, advocates and researchers must develop and test alternatives to the PTC hypothesis rather than adhere to a status quo that is contradicted by the evidence.

This paper is a project of Rethink Priorities—a think tank dedicated to informing decisions made by high-impact organizations and funders across various cause areas. If you are interested in Rethink Priorities' work, please visit our research database and subscribe to our newsletter.[9]

Disclosures

Author information

Jacob R Peacock, jacob@rethinkpriorities.org, https://orcid.org/0000-0002-4834-8132

Acknowledgements

Thank you to Ben Stevenson for research assistance. Thank you to Lewis Bollard, Marcus Davis, Kieran Greig, Janosch Linkersdörfer, William McAuliffe, Jared Piazza, David Reinstein, and Jacob Schmiess for their helpful feedback and Toni Adleberg, Ashley Chang, and Adam Papineau for editing.

Funding

This paper was initially funded as a project of The Humane League Labs. Neither The Humane League Labs nor its parent organization, The Humane League (https://thehumaneleague.org/), have reviewed or endorsed the final version of this paper.

Conflicts of interest

Jacob R Peacock serves as a trustee at the Food Systems Research Fund (https://www.fsrfund.org/) and an advisor to New Roots Institute (https://www.newrootsinstitute.org/). These organizations were in no way involved in this paper.

Open science

All supporting data and calculations are available at https://osf.io/5cqem/.

References

2019 Food & Health Survey. (2019). International Food Information Council. https://perma.cc/U9AW-9G5Y

A Consumer Survey on Plant Alternatives to Animal Meat. (2020). International Food Information Council. https://perma.cc/5AHS-GK6N

[9]Rethink Priorities website https://rethinkpriorities.org/, research database https://www.rethinkpriorities.org/research and newsletter https://www.rethinkpriorities.org/newsletter links.

Aggarwal, A., Rehm, C. D., Monsivais, P., & Drewnowski, A. (2016). Importance of taste, nutrition, cost and convenience in relation to diet quality: Evidence of nutrition resilience among US adults using National Health and Nutrition Examination Survey (NHANES) 2007–2010. *Preventive Medicine*, *90*, 184–192. https://doi.org/10.1016/j.ypmed.2016.06.030

Anderson, E. (2019). *Recode Decode at TED: Good Food Institute founder Bruce Friedrich explains why finding alternatives to meat is so important*. https://perma.cc/N3CA-YPRG

Animal Charity Evaluators. (2022a). *The Good Food Institute*. Animal Charity Evaluators. https://perma.cc/5TKE-XSHP

Animal Charity Evaluators. (2022b, March). *Consideration of Cause Areas*. Animal Charity Evaluators. https://perma.cc/5VKP-RHKS

Anthis, J. R. (2018, June 25). *3 Big Changes We Need in the Farmed Animal Movement*. Sentience Institute. https://perma.cc/5JQY-DG8H

Bianchi, F., Dorsel, C., Garnett, E., Aveyard, P., & Jebb, S. A. (2018). Interventions targeting conscious determinants of human behaviour to reduce the demand for meat: A systematic review with qualitative comparative analysis. *International Journal of Behavioral Nutrition and Physical Activity*, *15*(1). https://doi.org/10.1186/s12966-018-0729-6

Bianchi, F., Garnett, E., Dorsel, C., Aveyard, P., & Jebb, S. A. (2018). Restructuring physical micro-environments to reduce the demand for meat: A systematic review and qualitative comparative analysis. *The Lancet Planetary Health*, *2*(9), 384–397. https://doi.org/10.1016/S2542-5196(18)30188-8

Brachem, J., Krüdewagen, H., & Hagmayer, Y. (2019, September 19). *The Limits of Nudging: Can Descriptive Social Norms be Used to Reduce Meat Consumption? It's Probably Not That Easy*. https://doi.org/10.31234/osf.io/xk58q

Brunner, F., Kurz, V., Bryngelsson, D., & Hedenus, F. (2018). Carbon Label at a University Restaurant – Label Implementation and Evaluation. *Ecological Economics*, *146*, 658–667. https://doi.org/10.1016/j.ecolecon.2017.12.012

Bryant, C. J. (2022). Plant-based animal product alternatives are healthier and more environmentally sustainable than animal products. *Future Foods*, *6*. https://doi.org/10.1016/j.fufo.2022.100174

Cameron, B., & O'Neill, S. (2019). *State of the Industry Report: Plant-Based Meat, Eggs, and Dairy*. The Good Food Institute. https://perma.cc/4RL4-635P

Caputo, V., & Scarpa, R. (2022). Methodological Advances in Food Choice Experiments and Modeling: Current Practices, Challenges, and Future Research Directions. *Annual Review of Resource Economics*, *14*(1), 63–90. https://doi.org/10.1146/annurev-resource-111820-023242

Caputo, V., Sogari, G., & Van Loo, E. J. (2022). Do plant-based and blend meat alternatives taste like meat? A combined sensory and choice experiment study. *Applied Economic Perspectives and Policy*, 86–105. https://doi.org/10.1002/aepp.13247

Cargill, N., & Wiblin, R. (2018). *Bruce Friedrich makes the case that inventing outstanding meat replacements is the most effective way to help animals*. https://perma.cc/B782-TAQT

Carlsson, F., Kataria, M., & Lampi, E. (2022). How much does it take? Willingness to switch to meat substitutes. *Ecological Economics*, *193*, 1–10. https://doi.org/10.1016/j.ecolecon.2021.107329

Chicken and burger alternatives: Taste test results. (2018). Food System Innovations. https://perma.cc/NPN8-QYKC

Delon, N., Griffiths, Z., & Dillard, C. (2022). *Social norms: What they are and how they help and hinder farmed animal advocacy*. Mercy for Animals. https://perma.cc/7ATM-U388

Dupré, R. (1999). "If It's Yellow, It Must Be Butter": Margarine Regulation in North America Since 1886. *The Journal of Economic History*, *59*(2), 353–371. https://doi.org/10.1017/S0022050700022865

Elzerman, J. E., Hoek, A. C., van Boekel, M. A. J. S., & Luning, P. A. (2011). Consumer acceptance and appropriateness of meat substitutes in a meal context. *Food Quality and Preference*, *22*(3), 233–240. https://doi.org/10.1016/j.foodqual.2010.10.006

Friedrich, B. (2020, January 22). *Bruce Friedrich: Creating a New Agricultural Revolution*. Effective Altruism Forum. https://perma.cc/YT53-ME6Z

Friedrich, B., & Purvis, N. (2022, October 8). *Plant-Based Proteins Are Too Expensive*. Foreign Policy.

https://perma.cc/X3HM-FTML
Garber, L. L., Hyatt, E. M., & Starr, R. G. (2003). Measuring consumer response to food products. *Food Quality and Preference*, *14*(1), 3–15. https://doi.org/10.1016/S0950-3293(02)00030-7
Garnett, E. E., Balmford, A., Sandbrook, C., Pilling, M. A., & Marteau, T. M. (2019). Impact of increasing vegetarian availability on meal selection and sales in cafeterias. *Proceedings of the National Academy of Sciences*, 1–7. https://doi.org/10.1073/pnas.1907207116
Geijer, T. (2020, October 22). *Growth of meat and dairy alternatives is stirring up the European food industry.* ING Think. https://perma.cc/64GY-XCA8
GFI Research Program: 2019 Request for Proposals (RFP). (2019). The Good Food Institute.
Glanz, K., Basil, M., Maibach, E., Goldberg, J., & Snyder, D. (1998). Why Americans eat what they do: Taste, nutrition, cost, convenience, and weight control concerns as influences on food consumption. *Journal of the American Dietetic Association*, *98*(10), 1118–1126. https://doi.org/10.1016/S0002-8223(98)00260-0
Graça, J., Calheiros, M. M., & Oliveira, A. (2015). Attached to meat? (Un)Willingness and intentions to adopt a more plant-based diet. *Appetite*, *95*, 113–125. https://doi.org/10.1016/j.appet.2015.06.024
Graham, R. (2023, June 23). *Why So-Called Fake Meat Is Actually Better for Nature.* Sentient Media. https://perma.cc/7Y38-5EHU
Grundy, E. A. C., Slattery, P., Saeri, A. K., Watkins, K., Houlden, T., Farr, N., Askin, H., Lee, J., Mintoft-Jones, A., Cyna, S., Dziegielewski, A., Gelber, R., Rowe, A., Mathur, M. B., Timmons, S., Zhao, K., Wilks, M., Peacock, J. R., Harris, J., … Zorker, M. (2022). Interventions that influence animal-product consumption: A meta-review. *Future Foods*, *5*, 1–18. https://doi.org/10.1016/j.fufo.2021.100111
Hirsch, S. (2022). *Product placement in the meat substitute sector: Evidence from a spatial demand model.* 2022 Agricultural & Applied Economics Association Annual Meeting. https://doi.org/10.22004/ag.econ.322181
Hoek, A. C., Elzerman, J. E., Hageman, R., Kok, F. J., Luning, P. A., & Graaf, C. de. (2012). Are meat substitutes liked better over time? A repeated in-home use test with meat substitutes or meat in meals. *Food Quality and Preference*, *28*(1), 253–263. https://doi.org/10.1016/j.foodqual.2012.07.002
Hu, F. B., Otis, B. O., & McCarthy, G. (2019). Can Plant-Based Meat Alternatives Be Part of a Healthy and Sustainable Diet? *Journal of the American Medical Association*, 1547–1548. https://doi.org/10.1001/jama.2019.13187
Jalil, A. J., Tasoff, J., & Bustamante, A. V. (2019). Eating to save the planet: Evidence from a randomized controlled trial using individual-level food purchase data. *Food Policy*, *95*, 1–12. https://doi.org/10.1016/j.foodpol.2020.101950
Kankyoku, A. (2022, October 17). *The Animal Movement's Biggest Blind Spot.* Pax Fauna. https://perma.cc/RKJ6-G3ZX
Köster, E. P. (2009). Diversity in the determinants of food choice: A psychological perspective. *Food Quality and Preference*, *20*(2), 70–82. https://doi.org/10.1016/j.foodqual.2007.11.002
Krishna, A., & Elder, R. S. (2021). A review of the cognitive and sensory cues impacting taste perceptions and consumption. *Consumer Psychology Review*, *4*(1), 121–134. https://doi.org/10.1002/arcp.1069
Lusk, J. L., Blaustein-Rejto, D., Shah, S., & Tonsor, G. T. (2022). Impact of plant-based meat alternatives on cattle inventories and greenhouse gas emissions. *Environmental Research Letters*, *17*, 3–6. https://doi.org/10.1088/1748-9326/ac4fda
Malan, H. (2020). *Swap the Meat, Save the Planet: A Community-Based Participatory Approach to Promoting Healthy, Sustainable Food in a University Setting* [UCLA]. https://escholarship.org/uc/item/3pq4t2mz
Malan, H., Bartolotto, C., Wilcots, C., Angelis, P., Ferrone, A., Wible, C., Westbrook, E., Fabris, E., Wang, M. C., Slusser, W., Jay, J. A., & Prelip, M. L. (2022). Increasing the Selection of Low-Carbon-Footprint Entrées through the Addition of New Menu Items and a Social Marketing Campaign in University Dining. *Journal of the Association for Consumer Research*, *7*(4), 461–470. https://doi.org/10.1086/720450
Martin, C., Lange, C., & Marette, S. (2021). Importance of additional information, as a complement to information coming from packaging, to promote meat substitutes: A case study on a sausage based on vegetable proteins. *Food Quality and Preference*, *87*, 2–9. https://doi.org/10.1016/j.foodqual.2020.104058
Maze, J. (2019, October 21). *Plant-based meat can't lift Del Taco's traffic.* Restaurant Business. https://perma.cc/29BH-Q4A9

McHugh, L. (2022, December). *Should plant-based products be sold alongside meat?* IGD. https://perma.cc/5GXS-2JTH

McKenzie, J. (2022, March 25). *Reinventing meat to stave off climate crisis—and the next pandemic.* Bulletin of the Atomic Scientists. https://perma.cc/2DS9-S6GB

Mehta, T., & Balu, N. (2019, December 10). McDonald's could sell over 250 million Beyond Meat burgers in U.S. Annually: UBS. *Reuters.* https://perma.cc/G6GV-Q5UP

Mendez, S., & Peacock, J. (2021). *Milking It: Exploring the impact of plant-based milk in the US* (Report E019R02). The Humane League Labs. https://doi.org/10.31219/osf.io/j89qm

Mendez, S., Peacock, J., & Stevenson, B. (2023, April 13). *Inconsistent evidence for price substitution between butter and margarine: A shallow review.* Rethink Priorities. https://rethinkpriorities.org/publications/inconsistent-evidence-for-price-substitution

Michel, F., Hartmann, C., & Siegrist, M. (2021). Consumers' associations, perceptions and acceptance of meat and plant-based meat alternatives. *Food Quality and Preference*, *87*, 1–10. https://doi.org/10.1016/j.foodqual.2020.104063

Miller, R. (2021, February 26). *Insight of the Week: Significant Opportunities for Plant-Based Alternatives to Real Meat.* GlobeScan. https://perma.cc/69ZK-RGDL

New Harvest. (2021). *New Harvest Annual Report.* New Harvest. https://perma.cc/47SN-WE4L

Osman, M., & Thornton, K. (2019). Traffic light labelling of meals to promote sustainable consumption and healthy eating. *Appetite*, *138*, 60–71. https://doi.org/10.1016/j.appet.2019.03.015

Piazza, J., Ruby, M. B., Loughnan, S., Luong, M., Kulik, J., Watkins, H. M., & Seigerman, M. (2015). Rationalizing meat consumption. The 4Ns. *Appetite*, *91*, 114–128. https://doi.org/10.1016/j.appet.2015.04.011

Piernas, C., Cook, B., Stevens, R., Stewart, C., Hollowell, J., Scarborough, P., & Jebb, S. A. (2021). Estimating the effect of moving meat-free products to the meat aisle on sales of meat and meat-free products: A non-randomised controlled intervention study in a large UK supermarket chain. *PLOS Medicine*, *18*(7), 1–15. https://doi.org/10.1371/journal.pmed.1003715

ProVeg. (n.d.). *Convenience by design: How to make plant-based products easy for consumers and attractive to flexitarians.* ProVeg Corporate. Retrieved July 25, 2023, from https://perma.cc/LD3R-VBPU

Qammar, G., Mohy-ud-Din, G., Huma, N., Sameen, A., & Issa Khan, M. (2010). Textured soy protein (TSP) as pizza topping. *Nutrition & Food Science*, *40*(6), 551–556. https://doi.org/10.1108/00346651011090356

Rubio, N. R., Xiang, N., & Kaplan, D. L. (2020). Plant-based and cell-based approaches to meat production. *Nature Communications*, *11*(1, 1). https://doi.org/10.1038/s41467-020-20061-y

Savoie, J. (2018, August 26). *How to make an impact in animal advocacy, a survey.* Effective Altruism Forum. https://perma.cc/9ZE9-8L5A

Schouteten, J. J., De Steur, H., De Pelsmaeker, S., Lagast, S., Juvinal, J. G., De Bourdeaudhuij, I., Verbeke, W., & Gellynck, X. (2016). Emotional and sensory profiling of insect-, plant- and meat-based burgers under blind, expected and informed conditions. *Food Quality and Preference*, *52*, 27–31. https://doi.org/10.1016/j.foodqual.2016.03.011

Shanker, D., & Patton, L. (2020, January 22). Burger King Cuts Impossible Whopper Price on Slowing Sales. *Bloomberg.* https://perma.cc/8CF2-BH6G

Shapiro, P. (2018, January). *Clean meat: The clean energy of food.* TED. https://perma.cc/26FM-BQNF

Slade, P. (2018). If you build it, will they eat it? Consumer preferences for plant-based and cultured meat burgers. *Appetite*, *125*, 428–437. https://doi.org/10.1016/j.appet.2018.02.030

Sogari, G., Caputo, V., Petterson, A. J., Mora, C., & Boukid, F. (2023). A Sensory Study on Consumer Valuation for Plant-Based Meat Alternatives: What is liked and disliked the most? *Food Research International*, *169*. https://doi.org/10.1016/j.foodres.2023.112813

Southey, F. (2019, September 19). *Ikea challenges meatball "identity" with plant-based alternative: "We want to convert carnivores".* foodnavigator.com. https://web.archive.org/web/20220914031236/https://www.foodnavigator.com/Article/2019/09/19/Ikea-challenges-meatball-identity-with-plant-based-alternative-We-want-to-convert-carnivores

Splitter, J. (2020, January 30). *Consumers Perceive Plant-Based Foods To Be Healthier, Even When They*

Compare Labels. Forbes. https://perma.cc/FZ8C-W4NM

Stevens, A. (2021, April 22). *Will a 'Turing Test' for plant-based meat be passed if such a test is conducted by April 2023?* Metaculus. https://perma.cc/95ZT-H9DP

Szejda, K., Urbanovich, T., & Wilks, M. (2020). *Accelerating Consumer Adoption of Plant-Based Meat: An Evidence-Based Guide for Effective Practice*. The Good Food Institute. https://perma.cc/4MSR-BWWQ

Taufik, D., Verain, M. C. D., Bouwman, E. P., & Reinders, M. J. (2019). Determinants of real-life behavioural interventions to stimulate more plant-based and less animal-based diets: A systematic review. *Trends in Food Science & Technology*, *93*, 281–303. https://doi.org/10.1016/j.tifs.2019.09.019

The Good Food Institute. (2022). *2021 State of the Industry Report: Plant-Based Meat, Seafood, Eggs, and Dairy*. The Good Food Institute. https://perma.cc/LL76-9FC4

The Good Food Institute. (2023). *2022 State of the Industry Report: Plant-Based Meat, Seafood, Eggs, and Dairy*. The Good Food Institute. https://perma.cc/6HAB-RDT6

Theurer, B. M., Hernandez, A., Lazar, A., Bernstein, J. A., & Ackerman, W. (2019). *Global Food: I Can't Believe It's Not Meat*. Barclays. https://live.barcap.com/go/publications/link?contentPubID=FP2458995

Tonsor, G. T., & Bina, J. D. (2023, May 15). *Assessing Cross-Price Effects of Meat Alternatives on Beef, Pork, and Chicken Retail Demand in 2022*. https://perma.cc/E82N-4PDX

Tonsor, G. T., Lusk, J. L., & Schroeder, T. C. (2022). Market potential of new plant-based protein alternatives: Insights from four US consumer experiments. *Applied Economic Perspectives and Policy*, *45*(1), 164–181. https://doi.org/10.1002/aepp.13253

Tonsor, G. T., Lusk, J. L., & Schroeder, Ted C. (2021). *Impacts of New Plant-Based Protein Alternatives on U.S. Beef Demand*. https://perma.cc/CC6C-CVA7

Van Loo, E. J., Caputo, V., & Lusk, J. L. (2020). Consumer Preferences for Farm-Raised Meat, Lab-Grown Meat, and Plant-Based Meat Alternatives: Does Information or Brand Matter? *Food Policy*, 1–15. https://doi.org/10.1016/j.foodpol.2020.101931

Vandenbroele, J., Slabbinck, H., Van Kerckhove, A., & Vermeir, I. (2019). Mock meat in the butchery: Nudging consumers toward meat substitutes. *Organizational Behavior and Human Decision Processes*, *163*, 105–116. https://doi.org/10.1016/j.obhdp.2019.09.004

von Koeller, E., Neeru Ravi, Ema Tanovic, Lauren Taylor, & Malte Clausen. (2023, February 22). *Taking Alternative Proteins Mainstream*. BCG Global. https://perma.cc/T2A2-8KVH

Webber, J. (2019, July 9). *IKEA Just Made Its Vegan Hot Dogs Cheaper Than the Meat Version*. LiveKindly. https://perma.cc/KJ4M-A46M

Zane Swanson, Caitlin Welsh, & Joseph Majkut. (2023). *Mitigating Risk and Capturing Opportunity: The Future of Alternative Proteins*. Center for Strategic & International Studies. https://perma.cc/DP27-WS8Y

Zhao, S., Wang, L., Hu, W., & Zheng, Y. (2022). Meet the meatless: Demand for new generation plant-based meat alternatives. *Applied Economic Perspectives and Policy*, 1–18. https://doi.org/10.1002/aepp.13232