CHOICES
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Theme Overview: The Challenge of Providing Safe and Accessible Food for a Healthy Life

Jane Kolodinsky and Ruiqing Miao

JEL Classifications: Q19, D10, D13
Keywords: Food Quality, Food Safety, Food Waste, Grand Challenge, Plant-Based Meat

In late 2021, a committee appointed by the leadership of the Agricultural and Applied Economics Association developed a white paper on the grand challenge of ensuring that all people have safe, affordable, accessible, and acceptable food for leading a healthy and active life. To meet this grand challenge, we need to predict, identify, and explain causal relationships among policies and market conditions in the food system. Norbert Wilson led this effort, and the white paper is included as part of this theme of *Choices*. Collaborators included Lauren Chenarides, Jane Kolodinsky, and Kathryn Boys.

This theme includes papers based on presentations made during the June 2023 Council on Food, Agriculture and Resource Economics (C-FARE) webinar titled, "The Challenge of Providing Safe and Accessible Food for a Healthy Life." Linlin Fan presented a paper on food waste co-authored with Eliot Martin, Eliza Hallett, Brenna Ellison, and Norbert Wilson. The U.S. Department of Agriculture and the Environmental Protection Agency have set a goal to reduce food waste by half by 2030. Various solutions have been proposed, including making donations easier, standardizing date labels, feeding food waste to animals, and implementing consumer education campaigns. However, Fan's study found a gap between support for these food waste policies and their perceived effectiveness, indicating that people may vote in favor of certain policies but not necessarily change their behavior after the policies are implemented.

Joel Cuffey presented a paper on consumer spending on plant-based meat alternatives. The paper is co-authored with Lauren Chenarides, Wenying Li, Shuoli Zhao, and Brianna Adamo. Plant-based meat products use plant-based proteins to mimic the look, taste, and texture of animal-based meat, and they are often considered more environmentally friendly. However, the healthfulness of plant-based meat alternatives is less clear due to its higher processing, sodium content, and preservatives compared to animal-based meat. Cuffey and his co-authors find that although some consumers—particularly younger and wealthier individuals—may be receptive to adopting plant-based meat alternatives, the majority of households do not regularly purchase it. Price, taste, and existing habits of animal-based meat consumption remain significant factors limiting the demand and regular incorporation of plant-based meat alternatives into diets.

Kathryn Boys includes an article about the intersection of food safety and quality. Food safety refers to ensuring that food is safe for human consumption, while food quality refers to the nutritional value and visual appeal of food. The economic cost and public health burden of foodborne illnesses in the United States are significant, with an estimated annual cost of $78 billion. Boys discusses individual food safety concerns (e.g., food allergens, special dietary needs) that can have serious

Articles in this Theme:

health consequences as well as food fraud, where fraudulent ingredients or products are introduced into the food system, posing health risks and economic losses.

A recording of the original webinar can be found on the C-FARE website at https://www.cfare.org/items/challenge-of-providing.

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Grand Challenge: To Ensure That All People Have Safe, Affordable, Accessible, and Acceptable Food for Leading a Healthy and Active Life

Norbert Wilson, Lauren Chenarides, Jane Kolodinsky, and Kathryn Boys

JEL Classifications: Q18, Q13, I38
Keywords: Affordability, Food access, Food safety, Sustainability

According to The Sustainable Development Goals Report 2021, 2.37 billion people regularly face food security challenges. Additionally, the USDA Economic Research Service reported that 10.5% of U.S. households (13.8 million households) were food insecure (Rabbitt, et al. 2023). The COVID-19 pandemic challenged food access for some, especially the most vulnerable portions of society, including the low-income, elderly, and children. Additionally, COVID-19 shed light on the importance of the global food supply chain and the need to support its resiliency.

Frequently, consumers face an evolving set of food choices from changing technologies, production methods and locations, and places to acquire food. The resulting shifts in the food environments and markets generate a wide array of options to fit consumers' evolving ideas about food, health, and sustainability. At the same time, producers, processors, and other stakeholders strive to meet their organizations' goals through the efficient production, transformation, and distribution of foods. Yet even within this dynamic food system, COVID-19 exposed challenges in our food system, most notably when producers had difficulties shifting products from one distribution channel to another at the beginning of the pandemic. While innovation can help improve food safety, increasingly globalized agri-food supply chains mean that food safety challenges may have extensive geographic reach. In addition, agri-food supply chains are susceptible to food fraud, which can harm human health. Economic volatility and supply chain disruptions can increase the incentive and opportunity for such events. Changing conditions in the environment and climate will further complicate the path to meeting this grand challenge by introducing new and heightening existing risks to the safety and availability of agri-food products. Shaping agri-food systems and markets are policies from global, national, state, and private sector stakeholders.

To meet the grand challenge of food for all, we need analysis that identifies, predicts, and explains causal relationships of policies and market conditions in the food system. Agricultural and applied economics has the toolkit necessary to address many of these issues. However, this grand challenge touches diverse topics beyond economics, including public health, sustainable production systems, food science, and law. Thus, collaborations across multiple disciples are needed to offer holistic and actionable solutions to this grand challenge.

Key Questions:

1. What are the key risks, technologies, and emerging food market opportunities? How do we assess their impact on creating accessible, safe, affordable, and culturally acceptable food systems?
2. What policy instruments, if any, are needed to ensure a healthy, well-nourished population while enhancing the resilience and sustainability of the food supply (environment, economy, and community), considering affordability and acceptability?
3. How do we support food access to all people, especially the underserved, in ways that ensure food is available (sufficient supply), affordable (within economic means), accessible (physically reachable), and nutritious (meeting dietary needs)?
4. What are the most effective methods of providing food safety and nutrition information to help consumers optimize their food choices?
5. How do changing climate and environmental conditions affect the safety, availability, sustainability, and practices of agriculture and aquaculture production systems and related industries?

Key Outcomes:

1. An evidence base of the agri-food supply chain that informs public policy to
    - provide high-quality, nutritious food that is affordable, accessible, safe,
    - support food production systems that mitigate environmental degradation,
    - promote equity in employment, access, and health outcomes,
    - support stakeholders' needs, and
    - know if, when, and which interventions are warranted.
2. Measurements that can accurately identify communities facing low food access, such as food insecurity.
3. A food system that provides safe and affordable foods and allows consumers to make optimal decisions.

For More Information

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Who is Being Blamed for Food Waste

Eliot M. Martin, Eliza M. Hallett, Linlin Fan, Brenna Ellison, Norbert L.W. Wilson

JEL Classifications: Q19, D10, D13
Keywords: Blame, Food policy, Food waste

Food waste has commanded growing attention in recent years, with recent estimates suggesting that people fail to consume as much as 40% of food grown globally (Parfitt, Barthel, and Macnaughton, 2010; Buzby, Farah-Wells, and Hyman, 2014). Given the potential magnitude of food waste, researchers and policy makers are working to lower food waste, as noted in the United Nations Sustainable Development Goal 12.3 (reduce food waste by 50% by 2030). Policy makers need the citizenry's support to use policy to affect this change, but, as Oliver and Lee (2005, p. 926) stated, "Politicians are unlikely to pass laws that would offend large portions of their constituents and policies that aim to change individual behavior must be seen as legitimate by their target populations." Thus, support is contingent on which stakeholder citizens view as contributing to the problem (Lusk and Ellison, 2013; Thibodeau, Perko, and Flusberg, 2015). In this article, we study an unexplored area of food waste: attribution of blame. We assess consumers' attribution of blame for food waste to different stakeholders and analyze blame attribution predictors. Following the extant literature on blame attribution and obesity, we argue that the motivation to action and accept policy change has a root in individuals' blame for a societal problem.

A diverse set of entities is responsible for the food loss and waste problem and could contribute to practical solutions. ReFED (2016), a food-waste-oriented nonprofit, tracked loss and waste of food along each stage of the food system, attributing 16% of losses to the farm level; 13% to the supermarket, distribution, and grocery store level; 18% to the restaurant level; 42% to the residential level; and the remaining 11% to institutions, industry/manufacturing, and government. Researchers cite market conditions as drivers of loss at the farm level. Simultaneously, various supply chain management challenges and food marketing decisions are sources of loss between the farm and consumers (FAO, 2011; Minor, Thornsbury, and Mishra, 2020).

Given the relative size of food waste by consumers, a large and growing literature focuses on consumer behavior. However, this literature does not address consumer understanding of the contributors to food waste. Our article fills a gap in the literature by studying consumers' perceptions about which stakeholders contribute to food loss and waste. A better understanding of blame attribution will shed light on what food waste policies may garner more consumer support.

Data and Methods

In September 2017, we collected data for this study through Qualtrics. The sample of participants reflected the U.S. population based on race, gender, age, income, and education. Qualtrics administered the survey to U.S. residents over 18 years old who were the primary shopper in their household. Of the participants who consented to participate in the study (N = 1,506), 182 did not attribute blame to each stakeholder. We excluded these participants from the analysis. We also lost participants (N = 2) who did not report shopping behaviors, for a final sample of 1,322.

This study is part of a larger survey of a choice experiment about shopping behavior and food waste (see Fan, Ellison, and Wilson, 2021; Ellison, Fan, and Wilson, 2022). After the choice experiment, participants saw a series of questions about the attribution of the blame of food waste, shopping behavior, and food waste mitigation strategies. In this exploratory analysis, the outcome variables are the attributions of the blame of food waste of six stakeholders in the United States: farmers, individuals, grocery stores, government policies, food manufacturers, and restaurants and food service. Following Lusk and Ellison (2013), we asked respondents to assign blame attribution on a 3-point scale—"Do not blame at all" (1 point), "Somewhat blame," (2 points), and "Primarily blame" (3 points)—for each of the six key stakeholders. We also calculated the mean blame, which is the average blame score across all six actors.

The survey also assessed preferences for grocery shopping routines and the quantity of food respondents typically ate or left unconsumed (wasted) in their households. The key predictors for our analysis are the food waste mitigating strategies that participants

reported. We identify seven activities that align with food waste mitigation strategies. A key potential predictor of blame is the use of uneaten food. In the survey, we asked, "What does your household typically do with food that is not eaten?" Participants could answer: throw uneaten food in the garbage, give uneaten food to a pet, compost uneaten food, donate uneaten food, or other. We constructed a binary variable called Food Diversion, which was equal to 1 if participants stated that they gave uneaten food to a pet, composted, or donated uneaten food, and 0 otherwise.

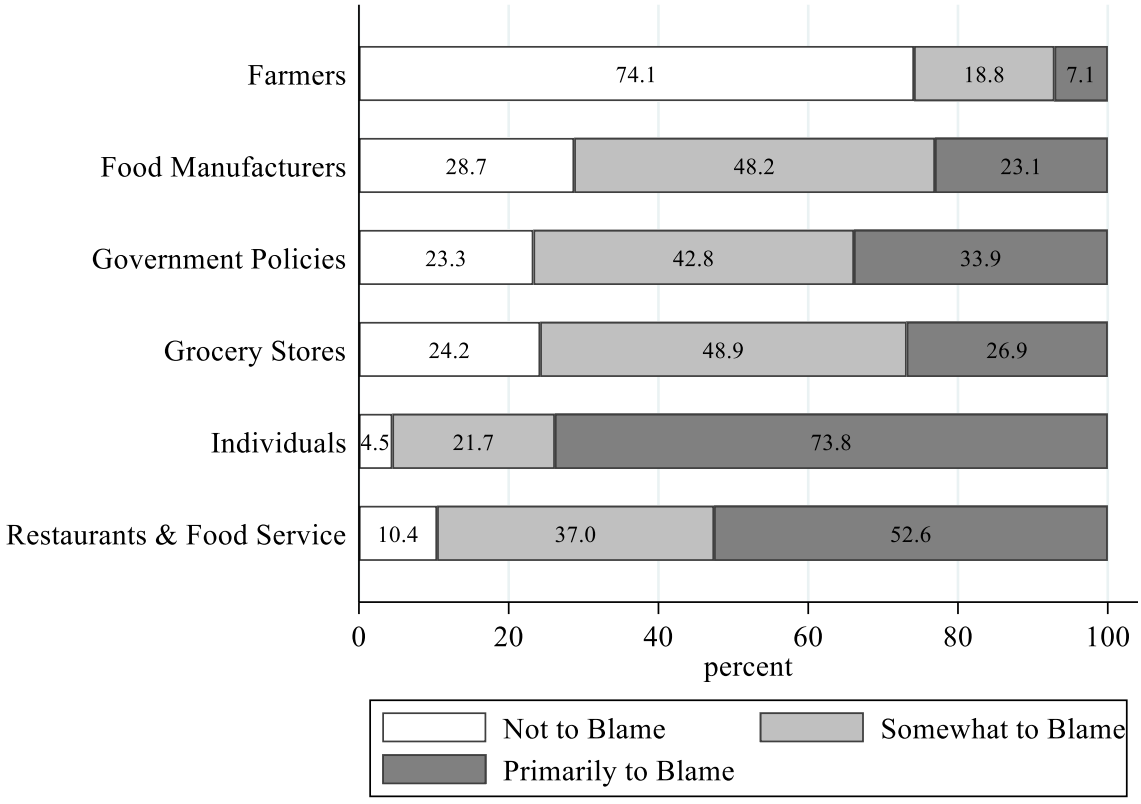
The other six food waste mitigating strategies are from a question about shopping behaviors. First, we asked, "Do you engage in the following activities related to grocery shopping?" For example, participants could answer "Yes" or "No" to statements such as "I typically use a list when grocery shopping" and "I typically buy items in bulk at the grocery store to save money." From there, we constructed six binary variables (Use of a Grocery List, Use of Coupons, Not Buying in Bulk, Online Grocery Shopping, Use of Meal Kits (e.g., Blue Apron, Sun Basket), and Shopping at Multiple Stores). We scored the variables with 1 if the participant engaged in the activity and 0 otherwise. We constructed the number of food waste mitigating activities as the sum of the seven binary variables. In addition, participants provided data on sociodemographic variables.

Social desirability is a concern for our research on food waste. We evaluated behaviors that can help reduce food waste. Thus, participants may report that they engage in more behaviors than they do. However, we were careful not to frame the questions with values or food waste mitigation connotations. For example, our questions were about shopping, not waste, as the study focused on food shopping. Further, we asked the shopping behavior questions before the blame questions, thus lowering participants' tendency to report more prosocial behaviors in response to the blame questions.

Results

We report the distribution of responses to the six blame attribution questions (see Figure 1). Overwhelmingly, respondents (73.9%) placed primary blame for food waste on individuals. The opposite was true for the blame on farmers, with 74.2% of respondents attributing no blame to farmers. Respondents generally had a similar blame attribution pattern for grocery stores, government policies, and food manufacturers. Each stakeholder had at least 40% of respondents mark "somewhat to blame." Like the blame score for individuals, most respondents (52.6%) placed primary blame for food waste on food service and restaurants, with only 10.4% of respondents who attributed no blame to these stakeholders.

Figure 1. Attribution of Blame for Food Waste to Stakeholders in the Food System (N = 1,322)



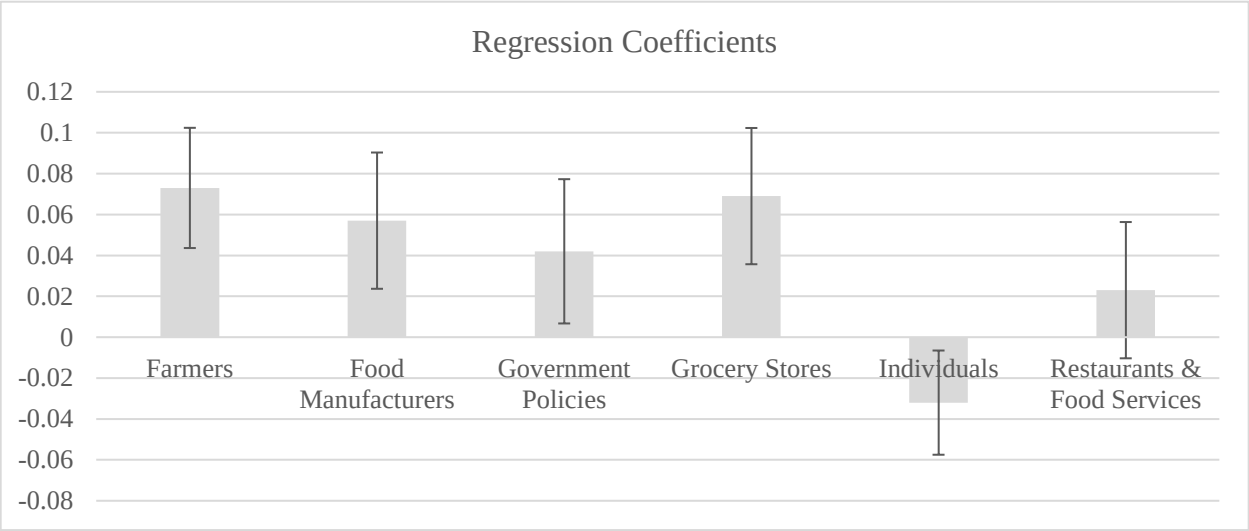
We now turn to the number of food waste mitigating activities to identify how the cumulative engagement in these food waste mitigation strategies was associated with blame in regression models. Figure 2 shows the coefficients of the number of food waste mitigation behaviors in regressions on blame scores (1–3) for farmers, food manufacturers, government policies, grocery stores, individuals, and restaurants and food service, respectively. The sociodemographic variables were controlled for in the regressions. The coefficients indicate the marginal effects (i.e., how the blame scores will change when people engage in one more food waste mitigating activity). We find that participating in more food waste mitigating activities was associated with a higher blame score for farmers, food manufacturers, government policy, and grocery stores. When people engaged more in food waste mitigation activities, they blamed individuals less (i.e., regression coefficient is negative). One explanation for this is that people who undertake food waste mitigation behaviors think that others do the same, forming an in-group bias. Social categorization literature suggests that individuals perceive a high level of similarity with other members of their in-group and will judge them as being similar to themselves. Conversely, individuals will see out-group members as dissimilar to themselves (Ashkanasy, 1997; Nikolaus, Nickols-Richardson, and Ellison, 2018).

Discussion

In the present study, respondents attributed the primary blame for food waste to individuals. The high level of individual blame attribution is consistent with the substantial estimated food waste that occurs at the residential level, according to ReFED (2016). Earlier research also found a tendency to blame individuals for obesity (Lusk and Ellison, 2013; Thibodeau, Perko, and Flusberg, 2015). Conversely, consumers seem to under-attribute blame to farmers, considering that the actual amount lost at the farm level is on par with the amount of food waste that occurs at other stakeholders besides the consumer. We assume that consumers may have an easier time conceptualizing food wasted at an individual or food service level than at the farm level. Respondents could also believe that waste at the farm is ultimately driven by other actors (e.g., high cosmetic standards). Ellison, Lusk, and Briggeman (2010) found evidence that consumers may have a positive view of farmers, which may explain the low attribution of the blame of farmers.

The models suggest that as respondents engage more in food waste mitigating activities, they primarily blame multiple actors. Thus, we assert that these respondents consider food waste a systemic problem with multiple actors responsible for food waste. These consumers attribute food waste to individuals (personal responsibility) and the broader food environment. We argue that these consumers know the complexity of the food environment, with its multiple contributors and antecedents to food waste and loss. Most respondents (59.51%) reported no or one food waste mitigating activity, and these respondents tended to assign "primarily to blame" to individuals and food service and restaurants. Following the logic that blame is a condition of perceived culpability, then policies to mitigate food waste targeted at individuals and food service and restaurants may at least be politically acceptable. These consumers would tend to support punitive policies to correct the failings of personal responsibility. However, the other 40% of respondents would argue for a more systemic change.

Figure 2. The Coefficients on the Number of Food Waste Mitigation Activities in Regressions on Blame Scores for Each Stakeholder in the Food System



Notes: 95% confidence intervals are presented along with the coefficients. Sociodemographic variables are controlled for in the regression models.

Conclusion

The findings of this study illustrate some potential points of concordance and discrepancy between how consumers attribute blame for food waste and where food waste occurs. The findings warrant careful consideration in developing practical approaches to mitigate food waste. In some instances, especially when considering upstream stakeholders in the food system, consumers may poorly understand food waste. Consumer education on waste at various food system levels may serve as an effective policy or intervention element. Consumers' perceptions of the blame for food waste appear to mirror their experiences and behaviors. Promoting food waste diversion, such as donations and composting, may change how consumers conceptualize who is to blame for food waste.

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Consumer Spending on Plant-Based Meat Alternatives

Lauren Chenarides, Joel Cuffey, Wenying Li, Shuoli Zhao, and Brianna Adamo

JEL Classifications: D12, D16, Q18
Keywords: Plant-based meat alternatives, Revealed preferences, Scanner data

It is estimated that the world population will reach 9 billion by 2050 (Boukid, 2021); meeting the food needs of this growing population is a global challenge. Meanwhile, inspired by sustainability and environmental stewardship initiatives, food production practices themselves have begun to shift. The production of alternative proteins is an example of a new production practice that continues to attract the attention of investors, the media, and stakeholders along the food supply chain. Dominating the market for alternative proteins are plant-based meat alternatives (PBMAs), which are designed to mimic animal-derived proteins while avoiding some of the environmental impacts of raising animals for meat. In addition to potentially alleviating the effects of the livestock industry on the environment and climate (Boukid, 2021), PBMAs may also lead to improvements in animal welfare and human health. This article describes various aspects pertaining to the current landscape of PBMAs, with a focus on consumer spending patterns and presents insights into the potential role of policy in shaping the market for alternative proteins.

Despite the public discourse surrounding PBMAs, these products have yet to become a consistent part of consumers' diets for several reasons. First, demand for animal-based meat continues to rise, as noted by Rubio, Xiang, and Kaplan (2020). One reason for sustained meat consumption is that it remains a significant cultural norm (Slade, 2018). Second, there are concerns about the level of ultra-processing in PBMAs, as highlighted by Hu, Otis, and McCarthy (2019).

Empirical research has illuminated challenges surrounding consumer adoption of PBMAs. Hoek et al. (2011) found that consumers often do not find the taste and texture of PBMAs as appealing as animal-based meat. A subsequent study by Hoek et al. (2013) explored long-term consumer acceptance of a plant-based diet using a repeated in-home adoption experiment. They found that consumers' preferences for meat substitutes could improve with continuous exposure. On the other hand, Elzerman, Van Boekel, and Luning (2013) observed that consumers hesitate to adopt PBMAs given the insufficient product information on packaging, price considerations, and incomparable taste and texture of meat. Graça, Calheiros, and Oliveira (2015) and Michel, Hartmann, and Siegrist (2021) further revealed that a strong attachment to meat and negative perceptions of PMBAs hinder consumers' willingness to switch to PBMAs. Moreover, White, Ballantine, and Ozanne (2022) employed Social Practice Theory to explore consumer practices related to PBMA consumption. Their findings underline the influence of social and cultural structures on the awareness and consumption of PBMAs. This resonates with the observations by Slade (2018) about the significant role of cultural norms in consumer choices, thereby creating a deeper understanding of the barriers and facilitators in the adoption of PBMAs.

Both Cuffey et al. (2023) and Neuhofer and Lusk (2022) utilized product purchasing data and found that PBMA buyers are primarily young, single, female, college-educated, employed, and of higher income. Interestingly, 86% of these buyers also purchased ground meat, suggesting that PBMAs are not completely displacing traditional meat products in the household. Zhao et al. (2023) added to this by showing that PBMAs may act as a complement to beef and pork, while substituting for chicken, turkey, and fish, offering unique implications for market strategies.

Taken together, while there has been a growing body of research on consumer demand for PBMAs, the majority of the literature has relied on either theoretical rationale or hypothetical economic experiments. In addition, previous research findings highlight the complexity of consumer attitudes and behaviors toward PBMAs, suggesting the need for a more comprehensive understanding of the determinants influencing their adoptions. In this article, we summarize actual consumer adoption patterns for PBMAs using real-world consumer purchasing data. We draw primarily on Cuffey et al. (2023), who used a nationally representative consumer panel dataset to examine adoption patterns for PBMAs.

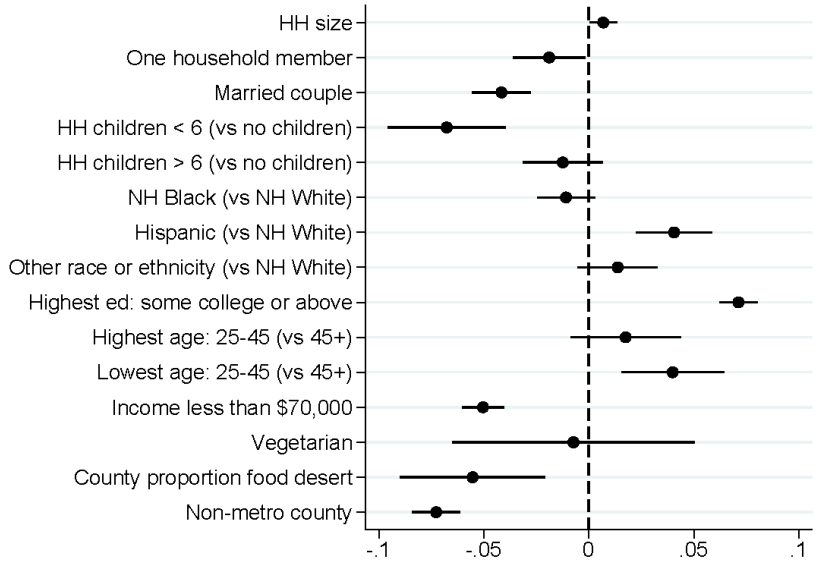
Who Buys Plant-Based Meat Alternatives?

This article uses the NielsenIQ Consumer Panel Data (CPD) from January 2014 through December 2019 to assess consumer spending patterns on PBMAs. This dataset captures detailed purchase information at the product level from households participating in the panel across various nationwide retailers. Further, NielsenIQ collects comprehensive data on the households, which includes aspects like household attributes, geographical information, and the assets they own. We focus on a sample of U.S. households that are part of the NielsenIQ panel. Specifically, the sample is restricted to households that have been in the panel for at least three consecutive years during the 2014–2019 period and have recorded at least one shopping trip per quarter. This selection results in a final sample comprising 52,022 households from most major metropolitan areas in the United States.

In our sample, 68% of households had never purchased PBMAs, 11% purchased PBMAs in only one month, and 21% purchased PBMAs in multiple months. For households that purchased PBMA in multiple months, we used the information on PBMA spending over time to define a household-level index of PBMA spending strength. This index combined information on how much a household spent on PBMA each month on average with how much monthly PBMA spending varied over time. We classified households as low spenders if their spending strength index was below the median index value. Medium spenders had a spending strength index between the median and 75th percentile, and high spenders had spending strength index values above the 75th percentile. Low spenders purchased PBMAs less frequently (1.18 times per month on average) and spent an average of $8.25 on PBMAs in months that they did purchase PBMAs. Medium-spenders purchased PBMAs more frequently (1.20 times per month on average) and spent an average of $8.73 on PBMAs in months that they purchased PBMAs. High spenders purchased PBMAs most frequently (1.63 times per month on average) and spent an average of $13.60 on PBMAs in months that they purchased PBMAs. Meat spending did not vary much across household types. Households that never purchased PBMAs spent an average of $21.32 per month on meat, while once-only, low-spenders, and medium-spenders all spent around $22 per month on meat ($22.15, $22.89, and $22.79, respectively). Only high spenders on PBMA spent less on meat ($20.81 per month on average). We classified vegetarian households as households who had never purchased meat. While high-spenders on PBMAs were more likely to be vegetarian, only 1% of high-spender households were classified as vegetarians.

Figure 1 shows the relationships between different variables describing households and whether that household has ever purchased PBMAs. Values to the right of the dotted line in the figure indicate that households with that characteristic were more likely to have ever tried PBMAs, and values to the left of the

Figure 1. Household Determinants for Ever Having Purchased Plant-Based Meat Alternatives



Notes: HH=household, NH=Non-Hispanic. Figure shows regression coefficients and 95% confidence intervals from a regression of an indicator for whether the household ever purchased plant-based meat alternatives on variables describing the household.
Source: Authors' depiction.

dotted line indicate that households with that characteristic were less likely to have ever tried PBMAs. Married couples and households with children under 6 are less likely to have tried PBMAs than other households. Relative to White households, Hispanic households were more likely to have tried PBMAs. Households with a college-educated individual were much more likely to have tried PBMAs, as were younger individuals. Lower-income households were less likely to have tried PBMAs. Households in counties with a greater proportion of the population in USDA-defined food deserts (low-income and low-access census tracts) are also less likely to have tried PBMAs, and resident of nonmetro counties are also less likely to have tried PBMAs.

What Happens When Households First Purchase Plant-Based Meat Alternatives?

In order to investigate what households think of PBMAs, we looked at how household spending on food changed when households first purchased PBMAs. Figure 2 shows monthly spending on PBMAs, total monthly food spending, and the share of food spending on different categories of food both before and after the initial purchase of PBMAs (month 0). By definition, there was no spending on PBMAs prior to month 0. In the month that households first tried PBMAs, they spent on average around $8 on PBMAs (panel a). Spending on PBMAs dropped to less than $2 per month on average in future months, indicating that households did not consistently continue buying PBMAs after the initial purchase. In the month that PBMAs were first purchased, total food spending increased by over $40 more than in previous months (panel b). This increase is substantially more than the PBMAs purchased, suggesting that households first try PBMAs in unusual months. When PBMAs are first purchased, the share of spending on dairy (panel e), deli (panel f), and dry grocery (panel g) products drops. One interpretation of these results is that households consider PBMAs to be substitutes to deli, dairy, and dry grocery products. At the same time, the share of spending on frozen food increases. Notably, the share of spending on meat does not change when households first try PBMAs.

In sum, a substantial proportion of consumers have not tried PBMAs. The characteristics of PBMA purchasers in our sample suggest that the price or cultural habits of meat consumption limit the consumer base. Further, PBMA spending does not appear to be a substitute for meat spending. Households continue to purchase substantial amounts of meat no matter how much they spend on PBMAs. Finally, since initial spending on PBMA happens in months with unusually large food spending overall, households may initially try PBMAs as part of a broader change in food consumption.

Discussion

PBMAs have attracted substantial interest recently, but consumers likely do not consider PBMAs to be a true substitute for animal-based meat. One potential reason is the higher price of PBMAs, and cultural norms of meat consumption also likely play a role. In addition to limited consumer adoption, there are barriers to entry for food manufacturers interested in participating in the PBMA sector. PBMAs require substantial investments in research and development and product formulation. Once the product is developed, the manufacturer must be able to scale up production, which may be difficult given the extensive processing required to produce PBMA products.

In the context of the current landscape of the PBMA options, sustainability has emerged as a primary goal for food manufacturers in the development of these products. However, a notable imbalance has arisen as manufacturers have prioritized sustainability over the incorporation of healthy ingredients. This imbalance could potentially hinder the success of many companies as consumers are presented with an increasing set of substitutable options in the market.

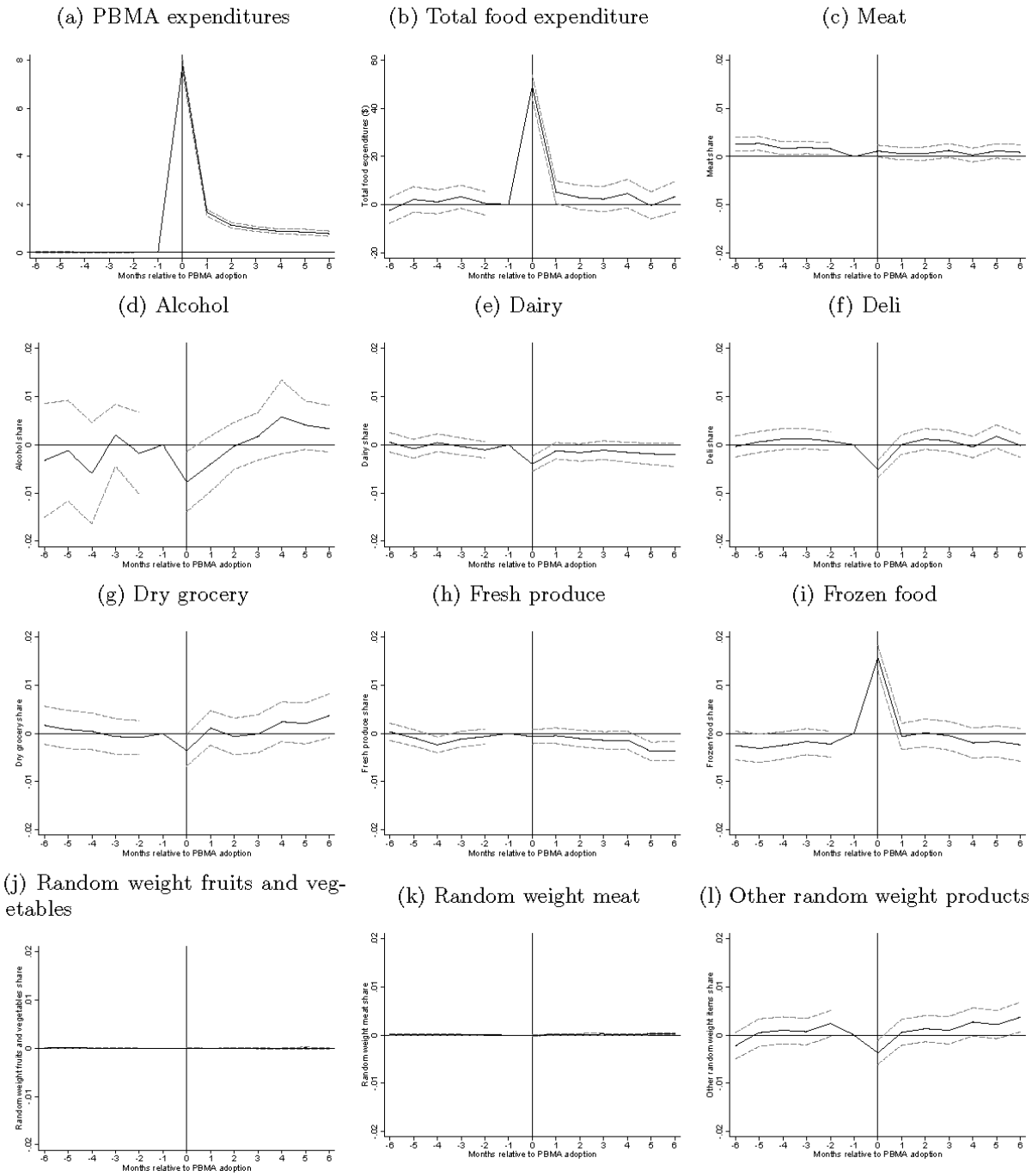
Plant-based meat alternatives are a response to the increasing consumer demand for healthier and more sustainable products. As the market for PBMAs continues to expand, an important consideration for market entrants is to establish a robust sourcing and procurement strategy to ensure a consistent supply of ingredients that yield products that align with consumer preferences, even if they entail a premium price point. However, the industry faces the ongoing challenge of crafting distinctive, economically accessible offerings amid a continuous influx of new market participants. Policy makers play a role in promoting sustainable food systems. Examples of policies that could promote sustainable food systems include encouraging research and development, providing incentives for sustainable farming practices, and promoting consumer awareness. These policies may help facilitate the transition toward a more environmentally friendly and socially responsible food industry. Further, international co-operation on policies related to alternative proteins can help address global food security challenges and reduce the environmental footprint of food production on a larger scale.

Conclusion

This article discusses the interplay between consumer choices, industry innovation, and policy development in the evolving landscape of plant-based meat alternatives. Despite their growing availability, PBMAs have not yet become substantial substitutes for animal-based meats, and their adoption is confined to specific demographic groups. Moreover, initial PBMA spending coincides with a broader shift in food consumption patterns rather than a reduction in meat purchases. These insights have

implications for industry stakeholders and policy makers, emphasizing the need for product development, targeted marketing, and supportive policy environments to boost PBMA adoption. Future research should also explore the long-term behavior of consumers and the influence of cultural factors in the adoption of PBMAs.

Figure 2. Spending on Plant-Based Meat Alternatives (PBMAs) and Spending Shares on Other Food Items before and after Initial Purchase of PBMAs



Note: Figure displays coefficients from regression models describing spending on PBMAs (panel a), total food spending (panel b), and spending shares on other food categories (panels c–l), both before and after household initially purchases PBMAs (month 0).
Source: Authors' depiction.

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From Contamination to Climate Change: Emerging Risks at the Nexus of Food Safety and Nutrition, and their Implications for Public Health

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Food shoppers are confronted with extensive amounts of information. Most often, consumers focus mainly on the price, brand, the type and extent of nutrition offered, and – potentially -other food production or processing attributes, such as kosher or organic certifications. In most developed countries, it is taken for granted that the human and pet foods available for sale are safe for consumption. However, this is not always the case. Every week, news reports detail new cases of food contamination, usually from microbes (especially bacteria and viruses) but also from a variety of parasitic, chemical, or physical contaminants such as plastics or metals.

The volume and often complex nature of food risk information can be overwhelming and lead consumers to either become hypervigilant or to largely ignore food safety risks. Additionally, food safety concerns become more complex when nutrition considerations are also considered. To offer further insight into these issues, this article begins by introducing food safety and some of the important linkages between food safety and nutrition. Following this, several contemporary food safety issues with nutrition implications are discussed.

What Food Safety Is… and Isn't

While there is no generally accepted definition of food safety (Oyarzabel and VanRenterghem, 2020), food safety broadly refers to the growing, handling, preparation, and storage of ingredients and foods in a way that prevents contamination and reduces the risk of foodborne illness. Food safety may, but does not necessarily, overlap with the concepts of food quality, food fraud, and food defense. Food quality applies to products that may still be safely consumed but because of spoilage or mishandling may offer less nutrition, changed texture or flavor, or become less visually appealing (e.g., due to bruising or wilting). Importantly, both food safety and food quality challenges are unintentional and are often due to mishandling and made worse with time. Food fraud is the deliberate deception of consumers using food products, ingredients, or package labeling for economic gain (GFSI, 2014). While not intended to affect a food's safety or available nutrition, certain types of fraud can detrimentally affect these attributes. The present discussion will focus primarily on food safety and the overlapping area of food fraud which can negatively impact a food's safety and nutrition.

So, why is this important? The economic cost of food safety failures and the burden to public health cannot be overstated. Despite extensive efforts to keep the U.S. food system safe, foodborne illness is still prevalent. The Centers for Disease Control and Prevention (CDC) estimate that one in six people living in the United States will be sickened by their food each year. Most of these cases are short-lived and successfully treated at home. More severe cases will require medical intervention. Each year, foodborne illnesses lead to 128,000 hospitalizations and approximately 3,000 deaths (FDA, 2023). Individuals with compromised immune systems, those who are pregnant, are elderly, and the unborn, are at particular risk from foodborne illnesses.

Foodborne disease outbreaks are defined as an incident in which two or more people experience the same illness from the same contaminated food or drink (CDC, 2015). As most cases of foodborne illness are remedied at home, the cause of the illness is not confirmed and is, therefore, not considered part of an outbreak. Between 2008 and 2015, among confirmed outbreaks where the source food was identified, chicken, turkey, pork, and beef products collectively accounted for 39% of outbreak-associated illnesses. Other commonly identified causes of outbreaks include fruits and vegetables (26% of outbreaks), animal products including eggs and dairy (12% of outbreaks), and fish and mollusks (9% of outbreaks) (CDC, 2023).

The economic cost of foodborne illness is substantial. Hoffman and Ahn (2021) estimated the economic burden of illness resulting from 15 pathogens that cause 95% foodborne illness cases. Using 2018 data to consider medical costs, productivity loss, and—in the case of deaths—the Value of a Statistical Life (VSL), Hoffman and Ahn found that these pathogens impose an economic burden of $17.6 billion annually. Given high inflation since this analysis was completed, and as medical care prices generally grow faster than overall consumer prices, this cost would now likely be substantially higher.

Linkages between Food Safety and Nutrition: Evolving Contemporary Issues

While often studied separately, food safety and nutrition are deeply interconnected. To achieve good health, individuals need to be both well-nourished as well as free from illness. The following discussion explores these linkages in the context of several evolving issues at the nexus between food safety and nutrition: changes in our understanding of diet-related disease, the nature and incidence of food fraud, and the implications of climate change on food safety.

Individual Food Safety Risk and Diet-Related Disease

When it comes to food, what is safe for some individuals may not be safe for all. Food allergies are a significant and growing health concern in the United States and several other nations that have adopted a Western lifestyle (Tang and Mullins, 2017). The most common type of food allergies, occur when an allergen binds to specific immunoglobulin E (IgE) antibodies which, in turn, triggers the release of histamine and other chemical substances, that cause an allergic reaction.. While mild food allergies may be inconvenient but tolerable (itchy mouth, hives, facial swelling), more severe allergies can be life-threatening (throat tightening, difficulty breathing, hypertension, circulatory collapse) or, in the most severe cases, are fatal. The economic burden of food allergies is significant. The economic cost of foodborne allergies among U.S. children alone has been estimated to be $24.8 billion ($4,184 per child) annually (Gupta et al., 2013), and the financial burden to individual households varies by socioeconomic status (Bilaver et al., 2016).

In addition, several other disorders can be triggered by food. Oral allergy syndrome and eosinophilic esophagitis occur alongside food allergies (NIAID, 2018). Food intolerance is an abnormal response to food that does not involve the immune system; rather, intolerances may occur due to malabsorption, enzyme deficiency, or other digestive issues. Food sensitivities do not yet have an official definition or medical diagnosis but are generally thought to result from inappropriate activation of the immune system (in this case Immunoglobulin G) to a particular food. Finally, autoimmune disorders, in which the body mistakenly attacks itself, can be triggered by food; Celiac disease, which can be triggered by the ingestion of gluten (a protein found in barley, rye, and wheat), is perhaps the best-known example of this.

Estimates indicate that 33 million Americans, approximately one in 10 adults and one in 13 children, exhibit some degree of food allergy (FARE, 2023). As most food allergy research is focused on children, much more is known about prevalence and effects on this population subgroup. Among children with food allergies, 39% had a history of severe reactions, and about 30% were reported to have multiple food allergies (Gupta et al., 2011). Importantly, data suggest that the incidence of food allergies differs by race and ethnicity. Black Americans are at the greatest risk of developing a food allergy (Keet et al., 2014). Moreover, compared to White children, Black and Hispanic/Latino children are at higher risk of adverse outcomes due to food allergies, including having increased rates of life-threatening reactions (e.g., anaphylaxis), emergency department visits, and associated morbidities (Mahdavinia et al., 2017).

Avoiding specific foods in one's diet requires great care and information. The Food Allergen Labeling and Consumer Protection Act of 2004 (FALCPA) requires labeling of eight major food allergens milk, eggs, tree nuts, peanuts, wheat, soy, fish, and crustacean shellfish. When FALCPA was passed, these eight allergens accounted for 90% of food allergies and serious allergic reactions in the United States. FALCPA requires allergens to be indicated in a food's ingredient list either in parentheses following the name of the ingredient (e.g., "flour (wheat)" or in a "contains statement" (e.g., "contains wheat") placed immediately after or next to the ingredient list. The list of ingredients that require labeling was expanded to include sesame seed in the Food Allergy Safety, Treatment, Education, and Research (FASTER) Act, implemented in 2023. In addition, recognizing that there are many more foods that can cause allergies or other reactions, the FDA issued draft guidance in 2022 concerning how the agency intends to evaluate the public health importance of lesser-known food allergens (FDA, 2022).

Avoiding specific foods also comes at an additional cost in both searching for and the expense of "free-from" foods. Families, particularly those in rural areas, face significant obstacles in finding appropriate foods and often need to travel significant distances to do so. Additionally, foods needed to address (or prevent) food-related illnesses are more expensive than their standard equivalents. Indeed, a gluten-free diet has been found to cost twice as much as a standard diet (Lee et al., 2019). Compounding this challenge, those with food allergies and other diet-related illnesses are also more likely to be from lower income households and have a higher prevalence of food insecurity than the general

population. While these families may be eligible for nutrition assistance programs, these do not help with this additional expense. The largest nutrition program, the Supplemental Nutrition Assistance Program (SNAP), does not fully consider the increased cost burden on families with food allergies (Brown et al., 2020). Other programs, such as the Summer Feeding Program and the Senior Farmers' Market Nutrition Program, do not adjust reimbursement to accommodate meal modifications for those with food-related conditions (USDA-FNS, 2024). Emergency food assistance efforts, such as food pantries and soup kitchens, also offer little help; nationally, only a handful of sites offer allergy-free options (Brown et al., 2020).

Food Fraud as a Food Safety and Nutrition Concern

Given the potential health impacts and geographic reach of food fraud, it is worth considering the risks posed by various types of food fraud and their food safety implications. Spink and Moyer (2011) classified several common types of food fraud. *Adulteration* occurs when all or some component of a food product, such as a high-cost ingredient, is not what is claimed on the product label. *Tampering* refers to instances in which a legitimate product and packaging are used in a fraudulent way. *Over-run* occurs when a legitimate product is made in excess of a production agreement; in such cases the excess product is sold, often through illegitimate marketing channels. This differs from *theft*, in which legitimate products are stolen and later sold as if they had been legitimately procured. This can occur when, for example, loaded tractor trailers are stolen and the food product contained in them is redistributed through standard (often discount) food retailers. *Diversion* is the sale or distribution of products outside of intended markets. Food products that are illegitimately made but designed to look exactly like or very similar to the authentic version are considered *counterfeit* or *simulated*, respectively.

While food fraud is not a widely discussed topic, it has significant economic and public health implications. It has been estimated that, globally, food fraud costs the food industry $30–$40 billion annually (MSU CVM, 2019) and that a single food fraud incident can cost a company 2%–25% of its annual revenue (GMA, 2010). Particularly relevant to the present discussion, though, are the potential public health consequences of food fraud. To be sure, not all cases of food fraud will have food safety or nutrition implications: Fraud through theft or diversion may not pose any additional risk to consumers. But nutrition and food safety impacts are possible in instances where the fraud involves the sale and consumption of illegitimate products or legitimate products that are not properly handled. Products adulterated with toxic substances—such as food coloring containing lead or unapproved color additives—pose a direct health threat. Instances where legitimate foods are stolen and temperature controls not maintained during redistribution or when "best before" date labels are changed (extended) increase the likelihood that food products will become unsafe for consumption.

Other types of food fraud may have adverse health impacts for vulnerable population segments. As one example, fraud in spices is common and often occurs through the addition of filler material, which can easily be disguised as the spice to increase volume and thereby reduce the seller's input cost. When the bulking agent is a benign plant material, for example, the fraud has purely economic implications. But should the bulking materials be an allergen, such as when ground peanut shells or almond husks are added to ground cumin, these fraudulent products can pose a life-threatening risk. Nutritional impacts can occur when the labeled amount of nutrition is not contained in a product, such as when ingredients containing important macro- or micro-nutrients are substituted with other (often lower cost) ingredients with lower nutrient availability. Here again, for some food consumers this may not be a problem. However, for those consumers depending on the nutrition offered by these foods, such as infant formula or nutritional drinks for older adults, this can have grave health implications.

The challenge of food fraud is not limited to markets with lax regulatory or inspection oversight; rather, this is a global problem affecting all countries where there is an economic incentive (and insufficient deterrent) to doing so. In the United States, there were at least 153 identified cases of food fraud between 2015 and 2021.[1] While this number may seem low, the value and damages of each of these incidents is significant. Because of the obscure nature of this crime, these identified cases are certain to be a lower bound of the actual prevalence of U.S. food fraud. Importantly as well, the reported number of cases has followed a general upward trend; however, it is unclear whether this is due to an actual increase in the number of cases or to improvements in surveillance and reporting. The distribution of these cases across raw agricultural commodities and prepared foodstuffs varies considerably. Seafood animals and products, meat, cereals, flour, and starch products are the products most subject to fraud in the United States. Among these U.S. cases, most of the food fraud consists of adulteration (46.1%) or fraudulent documentation (39.1%). Many fewer cases are due to food processing or manufacturing without inspection (6.2%), in unapproved premises (5.0%), due to expiration date changes, or the unauthorized or unsuitable transport of food (0.9%).

[1] Author calculation using data from *HorizonScan (https://horizon-scan.fera.co.uk/)*.

Linkages between Climate Change, Food Safety and Nutrition

Several studies have considered questions concerning the impact of climate change on food security; in general, these studies have concluded that climate change will affect food security by disrupting food production and access. Relatively less is known about the complex and important linkages and implications of climate change for food safety and human nutrition. To address this, national and multinational efforts are considering these issues (FAO, 2020).[2] To date, studies suggest that climate change is likely to increase the risk of foodborne illness and chemical hazards in food (Ziska et al., 2016). Elevated temperatures and precipitation volatility are expected to increase exposure to some pathogens, toxins, and chemical contaminants. Many food and water pathogens - including *E. coli*, *Vibrio* spp., and nontyphoidal *Salmonella* spp.—favor warmer and wetter growing conditions which, in turn, could increase the pathogen load in soils and the potential for crop contamination. In addition, altered and extended summer seasons are expected to affect the frequency and severity of seasonal foodborne diseases (FAO, 2020). Cucurbits -which include cucumbers, melons, squashes, and pumpkins—may be particularly vulnerable to this contamination as they are grown in direct contact with soil.

Increases in extreme weather events, changing sea and ambient air temperatures, and elevated carbon dioxide levels are also expected to have a profound impact on exposure to chemical contaminants, the prevalence of naturally occurring toxins, and nutrient availability in food. Elevated sea surface temperatures will contribute to a greater accumulation of mercury in fish (Ziska et al., 2016). This poses food safety risks as consumption of methylmercury (the form of mercury that can be absorbed by humans) can have adverse neurological effects and affect the development of children. The risk of mycotoxin accumulation in fields and in the storage of harvested products is also expected to increase. Mycotoxins are toxins produced by some fungi, exposure to which can have toxic effects on the kidneys and the reproductive and immune systems (FAO, 2020); is known to be a primary cause of liver cancer (WHO, 2015); and has contributed to micronutrient deficiencies in children in developing countries (Watson et al., 2016). Finally, it is anticipated that climate change will also affect the nutrient availability in foods. Due to increasing levels of atmospheric carbon dioxide, the concentrations of protein and essential minerals in most plant species will decrease (Ziska et al., 2016). As such, the nutritional value of many important food crops, including rice and wheat, may fall below current norms.

In addition to these detrimental impacts, studies have explored a variety of other linkages between climate change and food safety and nutrition. Among these are the impacts of increasing water and air temperatures. Harmful algal blooms occur when there is an abundance of one or more of the 300 harmful species of algae in an area; warmer seas, ocean acidification, and other food impacts of overfishing have led to a global increase in the number and duration of these blooms FAO (2020). Phycotoxins produced by these algae can accumulate in fish and shellfish and can induce a variety of seafood intoxications -including Diarrhetic Shellfish Poisoning, Neurotoxic Shellfish Poisoning, and Amnesic Shellfish Poisoning - in those who consume them (Grattan et al., 2016). Climate change will also pose increased challenges for the safe storage of temperature-sensitive ingredients or foods as the rise of ambient temperatures will likely require expanded or upgraded chilling or freezing technologies.

The economic burden of this technology upgrading is likely to be disproportionately felt by those in developing countries, who will be most in need of upgrading their current cooling capacity due to their lower initial stock of this equipment and who will likely experience the largest temperature changes (James and James, 2010). Many other emerging food safety issues and concepts that will be influenced by climate change have been identified, including emerging pollutants, novel food production systems, novel food sources, geoengineering measures, and digitization and other technological advancements (FAO, 2020).

Conclusions

Despite significant investment in efforts to reduce the prevalence and increase the monitoring and prediction of food safety hazards, foodborne illness continues to pose very significant public health and economic burdens. Evolving environmental and human health conditions, as well as market opportunities and incentives, continue to create new food safety challenges. These changes, in turn, have direct and indirect linkages and often negative implications to access and availability of safe food, and the nutritional quality of it. Anticipating, understanding, and meeting these emerging challenges will require sustained, creative, and transdisciplinary research, significant private and public sector investment, and innovative policy development.

[2] One such initiative was led by the U.S. Global Change Research Program (https://www.globalchange.gov/), which facilitates collaboration and cooperation across 15 federal agencies.

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