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Gene-Edited Food Adoption Intentions and Institutional Trust in the United States: Benefits, Acceptance, and Labeling☆

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Abstract New gene editing techniques, such as CRISPR-Cas9, have created the potential for rapid development of new gene-edited food (GEF) products. Unlike genetically modified organism foods, there is limited research and literature on U.S. public opinions about GEFs. We address this knowledge gap by examining how crop-based GEF adoption is linked to public trust in institutions and values using the Theory of Planned Behavior. We employ ordinal regression models to predict adoption intentions (direct benefits, acceptability, willingness to eat, and labeling) using a unique and nationally representative survey of n = 2,000 adults in the United States. We find that adoption hinges on public trust in institutions overseeing GEF development, especially trust in university scientists. The 29 percent of Americans likely to adopt GEFs highly trust government food regulators and the biotech industry. A nearly equal number of likely non-adopters distrust current regulatory systems in favor of consumer and environmental advocacy groups. However,

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most Americans (41 percent) are uncertain about GEF adoption and whom to trust. Although 75 percent of Americans want GEFs labeled, few trust government agencies who have authority to issue labels. Our findings suggest public trust in GEFs and labels can only be obtained by tripartite oversight by universities, advocacy groups, and government food regulators.

Introduction

US publics have grown increasingly interested in knowing more about their food and how it is produced. This is evidenced by the rise of alternative food systems and movements—such as organic production and community-supported agriculture (Friedland 2010; Glenna and Jussaume 2007; Raynolds 2000; Som Castellano 2016)—and growing visibility of food labels, such as USDA Organic, Non-GMO Project Verified, Fair Trade, and various eco-labels (Bain and Selfa 2017; Darnall, Ji, and Potoski 2017; Howard and Allen 2010). Motivating the creation of such labels and the rise of alternative systems of production are underlying concerns about agrifood systems and changes, such as globalization, industrialization, and concentration of power by agribusinesses. Such changes raise public concerns about the potential unequal distribution of social, environmental, and economic benefits and harms (David and Thompson 2008; Som Castellano 2016). Arguably, one of the most important changes in the U.S. agrifood system over the past quarter century has been the development and diffusion of genetically modified organism (GMO) food crops (Bruce 2017; Sylvester, Abbott, and Marchant 2009). More recently, gene editing technologies—sometimes classified under the broad terms *new breeding technologies* and *new genomic techniques*—have been developing rapidly over the past decade.

The potential introduction of gene edited foods (GEFs) into agrifood systems has reinvigorated discussions about the role of biotechnologies in agriculture and food systems in the United States and around the globe (McFadden et al. 2021). Proponents of GEFs claim that such techniques will revolutionize food systems (Hall 2016) by improving food nutrition, taste, appearance, and shelf life, as well as providing agronomic benefits such as resilience against drought, diseases, and pests (CAST 2018). Gene-edited crops are also touted as a means for improving global food security through increased crop yields and more efficient water use (Bailey-Serres et al. 2019; Qaim 2020). However, many consumer and environmental groups express concerns that these new foods may only benefit a few powerful agribusiness actors, while posing risks and potentially harmful unintended consequences to farmers, consumers, and the environment (Bartkowski et al. 2018; Helliwell et al. 2017; Helliwell, Hartley, and Pearce 2019).

Differences between GEFs and GMOs may influence public perceptions and attitudes toward GEFs. Gene editing is performed using genetic engineering techniques such as CRISPR-Cas systems, TALENs, and zinc finger nucleases, which can make changes to the DNA within a single organism.[1] GEF scientists and supporters often argue that the final edited organisms resemble ones that could be hypothetically created in nature or through a longer process of traditional breeding (Bain, Lindberg, and Selfa 2020; Van Vu et al. 2022). By contrast, GMO engineering processes typically transfer genes from one species into the DNA of another species to create a *transgenic* organism that is unlikely to be found in nature (CAST 2018; FSA 2021). By describing GEFs as "natural," proponents seek to divorce GEFs from GMOs to encourage public acceptance and minimal regulations of gene-edited products (Bain et al. 2020; Doxzen and Henderson 2020; Siebert, Herzig, and Birringer 2022). This differentiation strategy and positive GEF media coverage may already be influencing public attitude formation. Public-facing GEF media publications between 2015 and 2020 frequently framed GEFs as distinct from GMOs, and media coverage generally presented positive or balanced analyses of possible benefits versus risks (Dahlstrom et al. 2022).

There is an immediate need to gauge emerging public opinions about GEFs at this early stage since many GEFs are in development (Dima, Heyvaert, and Inzé 2022; EU-SAGE 2022). As of 2022, only two GEFs have reached commercialization—in the United States, a soybean oil, and in Japan, a tomato variety—and both are being marketed with health and nutrition claims (Waltz 2021). Studying public opinions of GEF is important for several reasons. First, governance organizations can utilize this information to make responsible, informed, and inclusive decisions regarding biotechnology and food policy (Ishii and Araki 2016; Lusk, McFadden, and Wilson 2018; Wu, Ramesh, and Howlett 2015). Also, public and private research institutions and companies working to develop GEFs can benefit by knowing and considering public perspectives. By doing so, they may avoid or mitigate GEF public acceptance challenges linked to social, ethical, and governance concerns around labeling and risk/benefit distribution (Selfa, Lindberg, and Bain 2021). Failure to consider and account for public views and concerns may result in a repeat of the long and contentious GMO food debate, albeit with GEFs at the center.

The GMO food debates evolved around food safety concerns; environmental and social risk/benefit distributions; a lack of public trust in government food regulators and the agriculture biotechnology industry; and a failure to account for deeply rooted social values that inform food choices (Bain and Dandachi 2014; Delwaide et al. 2015; Glenna and Ransom 2021; Lang 2013; Lassen and Sandøe 2009; McFadden and Lusk 2016). Mandatory bioengineered labels will begin to appear on food products in 2022 as part of the National Bioengineered Food Disclosure Standard (NBFDS), thus requiring all GMOs to carry the federally mandated label. Although GEFs are exempt under NBFDS, the new bioengineered label may stimulate public interest in new genomic food products generally, and GEFs specifically (Cummings and Peters 2022a).

Although there is a large body of research on GMO foods, there is limited information on attitudes about GEFs in the United States. Previous work has largely focused on willingness-to-pay/buy/consume economic and marketing experiments for specific hypothetical GEF crops or food products (Caputo, Lusk, and Kilders 2020; Kilders and Caputo 2021; Marette, Disdier, and Beghin 2021; Shew et al. 2018). While economic considerations are important, missing from the literature is a sociological investigation into how GEF perceptions and adoption are linked to institutional trust. We address this knowledge gap by presenting data from a unique and nationally representative public opinion survey of GEFs in the United States. We focus on foods containing gene-edited plants or crops and not animals or livestock, which carry unique ethical considerations (Siegrist and Hartmann 2020). Our purpose is to understand how GEF adoption intentions (measured by direct benefits, acceptability, willingness to eat, and labeling) are influenced by institutional trust. Our data consist of a cross-sectional web panel sample of n = 2,000 adults in the United States. Our study addresses two research questions. First, what do Americans think about the potential benefits, acceptability, willingness to eat, and labeling of plant-based GEFs? Second, is the potential adoption of foods made with gene-edited crops dependent on the public's trust in the institutions tasked with overseeing their development and regulation?

Our present analysis extends previous GEF perceptions research by Cummings and Peters (2022a, 2022b) in several unique ways. To start, we focus on the public's trust in institutions tasked with developing and overseeing GEFs and how trust affects potential adoption intentions. We examine these relationships using ordinal regression models that are theoretically grounded using a conceptual model of GEF adoption using the Theory of Planned Behavior (TPB) and institutional trust concepts. By contrast, Cummings and Peters (2022a) only focused on willingness to eat and purposeful avoidance of GEFs, and Cummings and Peters (2022b) presented brief descriptive counts with neither statistical analysis nor theory.

Previous Research and Conceptual Approach

Public Perceptions of GEFs

Although a large body of research exists on perceptions and attitudes of GMO foods, there is a paucity of research on how the U.S. populace views GEFs. Busch et al. (2022) recently published initial findings to inform our emergent understanding of GEF perceptions. Using data from the United States and four European nations, their findings indicate Americans held the most supportive views of GEFs as compared to the other nations studied, with 59.1 percent categorized as strong or slight supporters, 27.2 percent as neutral, and 13.7 percent as opponents. Of the 45 percent of Americans that said they have heard about gene editing technologies, 50.1 percent rated their knowledge of gene editing as very low to below average. It is worth noting that the survey was not representative and contained more women, people under 60 years of age, and those with higher educations. Another recent paper by Cummings and Peters (2022a) found that purposeful avoidance and unwillingness to eat GEFs was driven by food ethics, strong religious beliefs, anti-technology attitudes, older age, and female gender identity. Furthermore, consumers made no distinction between eating raw or processed GEFs, suggesting avoidance is driven by values instead of the characteristics of the food. Their findings were based on a nationally representative sample of the U.S. population.

Other U.S. GEF research has largely focused on willingness-to-pay or willingness-to-eat experiments with specific food products. Shew et al. (2018) conducted a multi-country experiment assessing consumers' hypothetical valuation and acceptance of GMO and GEF rice. Over 55 percent of U.S. respondents said they would consume both types of rice, followed next by Australia (51 percent), Canada (47 percent), Belgium (46 percent), and France (30 percent). A study by Caputo et al. (2020), done on behalf of the FMI Foundation, consisted of a choice experimental design examining consumer willingness-to-pay and beliefs, knowledge, understanding, and acceptance of gene-edited tomatoes, spinach, and pork. Approximately 50 percent had little awareness or knowledge of GEFs, and most held negative views toward these foods. Caputo et al. (2020) also found that providing information about environmental benefits mitigated some concerns about risks. Marette et al. (2021) compared U.S. and E.U. consumers' willingness-to-pay for GEF versus GMO apples. They found that providing information to American respondents did not systematically influence their valuations between GEF and GMO apples. In addition, Americans held more positive views toward GEFs as compared to Europeans, which is similar to Busch et al.'s (2022) findings. Marette et al.'s (2021) U.S. sample was not representative and was confined to a small Midwestern city that is home to a large state agricultural university. While economics and the types of food products are important considerations, missing from the literature is how GEF perceptions and adoption are linked to complex values and institutional trust.

Outside of the United States, research is revealing more initial public perceptions and attitudes toward GEFs. In Norway, a coalition of private and public organizations (GENEinnovate 2020) conducted a nationally representative survey across age, gender, and geographical region. A key finding was that more consumers held positive attitudes toward gene editing applications in agriculture and aquaculture *if* the applications produced some societal benefit or contributed to environmental and climate sustainability. Nevertheless, over half of respondents expressed concern that GEFs may pose risks to human health and the environment. In the United Kingdom, the Food Standards Agency (FSA 2021) found that although consumers had low knowledge and awareness of GEFs, they nonetheless strongly supported regulations and transparent labeling of GEFs. In Japan, Kato-Nitta et al. (2019) found that the general public held more favorable views of GEFs as compared to GMOs, but people still thought GEFs had fewer benefits and posed greater risks than conventional crops. Farid et al. (2020) examined Japanese university business and economic students' acceptance of GEFs. Their findings suggested that science communication and increased scientific knowledge can increase acceptance and trust in GEFs. Ferrari et al. (2021) researched Dutch and Belgian Gen Z and Millennial attitudes toward labeling GEFs and GMOs. The data demonstrated a general preference for GEFs and GMOs to possess labels, albeit not necessarily the same label. In Canada, Yang and Hobbs (2020) examined how hierarchical versus egalitarian worldviews influenced public acceptance of GEFs.

The brief literature on GEFs highlights the complexities and heterogeneity of views and attitudes about these new genomic food technologies within and across cultures. A common theme among existing research findings is that despite heterogeneity of surveyed publics, there is still a notable preference for conventionally bred foods, and GEFs are preferred over GMOs (Beghin and Gustafson 2021; Borrello, Cembalo, and Vecchio 2021; Caputo et al. 2020; Marette et al. 2021; Muringai, Fan, and Goddard 2020; Son and Lim 2021; Yang and Hobbs 2020).

GMOs and GEFs: A Continuation of Existing Tensions?

The proliferation of GMO crops and foods since the mid-1990s has been a contentious issue, although public perceptions differ by social contexts and across time (David and Thompson 2008; Kinchy 2012; Pechlaner 2012). The U.S. experienced less public resistance to GMOs than what was observed in Europe and other parts of the world (Bain and Dandachi 2014). However, a social movement in opposition to GMOs gained momentum over the past two decades in the United States, resulting in greater demand for non-GMO products among the public (Bain and Selfa 2017; Castellari et al. 2018; Pechlaner 2020). The non-GMO movement achieved a major success in 2016 when the U.S. Congress established the NBFDS (or P.L. 114-216), which requires food producers to label bioengineered products like transgenic GMO foods (Federal Register 2018). Food labels provide important informational cues to inform consumer marketplace choices (Kolodinsky, Morris, and Pazuniak 2019). An important caveat is that most current GEFs do not fall within the federal definition of a bioengineered food, which may create public backlash once GEFs enter the marketplace. Much of the non-GMO movement centered on the argument that consumers have the right to know what their food is and how their food is produced (Pechlaner 2020; Strauss 2018). This argument is similar to those for other food labels such as USDA Organic, Non-GMO Project Verified, Fair Trade, and various ecolabels (Bain and Selfa 2017; Darnall et al. 2017; Howard and Allen 2010).

Scholars have examined how current and past GMO controversies might influence emergent attitudes toward GEFs (Bain et al. 2020; Bruce and Bruce 2019; Helliwell et al. 2017; Macnaghten and Habets 2020). There is a large body of research stretching back to the late 1990s that documents the factors influencing GMO attitudes and acceptance, or lack thereof. To briefly summarize this extensive literature, GMO acceptance and adoption has been linked to the perceived risks and benefits of GMOs; to knowledge about science generally and genetic modification specifically; to ideas about nature and naturalness; to the importance of consumer information when making food choices; and to the potential long-term risks to human health and the environment (Clapp and Fuchs 2009; Costa-Font, Gil, and Bruce Traill 2008; David and Thompson 2008; Devos et al. 2008; Doxzen and Henderson 2020; Du 2012; Frewer et al. 2004; Hallman et al. 2003; Hossain et al. 2003; Hudson, Caplanova, and Novak 2015; James 2018; Siebert et al. 2022; Siegrist and Hartmann 2020). In addition, more marginalized segments of society tend to oppose GMOs, such as women, people over 65 years of age, those with lower incomes, and racial and ethnic minorities (Costa-Font and Gil 2012; Ganiere, Chern, and Hahn 2006; Siegrist 2000).

In particular, previous work revealed that trust in experts and institutions was a crucial factor impacting public risk–benefit perceptions of GMO foods and genomic technologies (Connor and Siegrist 2010; Moon and Balasubramanian 2004; Peters et al. 2007). In a study of Swiss citizens, Siegrist (2000) concluded that trust in institutions positively influenced benefit perceptions and negatively impacted risk perceptions of GMO technologies, which determined acceptance. Priest, Bonfadelli, and Rusanen (2003) found that the "trust gap," or differences in trust between environmental versus industry organizations, was the key predictor of support for GMO food applications in both the United States and the E.U. Lang and Hallman (2005) determined that the public had the most trust in GMO evaluators (defined as scientists, universities, and medical professionals), moderate trust in watchdog groups (consumer and environmental advocacy groups), and the least trust in merchants (grocery actors, agrifood industry, and farmers). Interestingly, respondents lacked trust in the federal government, a key institutional actor overseeing and regulating GMO foods. Low trust in the federal government may act as a barrier to GMO acceptance (Lang and Hallman 2005) and potentially GEF acceptance. Studies by Hamm, Smidt, and Mayer (2019), Lang (2013), and Park, Lee, and Peters (2017) concluded that trust around GMOs can be strengthened or weakened through informational channels and social interactions with a wide range of experts, institutions, and social networks, demonstrating possible avenues for influencing trust with emerging technologies such as GEFs.

Conceptual Model of GEF Adoption

To understand the potential adoption of GEFs among the American public, we combine concepts from the TPB and institutional trust to develop our conceptual model, presented in Figure 1. The TPB (Ajzen 1991) and other similar models based on it have been extensively applied in the sociology of agriculture to understand farmer and landowner decision-making (Floress et al. 2017; Gao and Arbuckle 2022; Lu et al. 2022; Reimer, Weinkauf, and Prokopy 2012; Roesch-McNally, Gordon Arbuckle, and Tyndall 2017; Ulrich-Schad et al. 2016). Institutional trust impacts public perceptions of the risks and benefits linked to new technologies, as documented by Beck (1992), Giddens (1990), and Hardin (1996). In the case of GMOs and GEFs, uncertainty about risks and unintended consequences, poor knowledge of the technologies, and limited power to effect changes in the agrifood system drive people to rely on their trust in institutional systems to protect them from harm (Farrell 2009; Peters 2019; Peters et al. 2007). It is worth noting that when examining trust and agricultural biotechnologies, it should not be passively assumed that that the public *should* trust biotech experts and

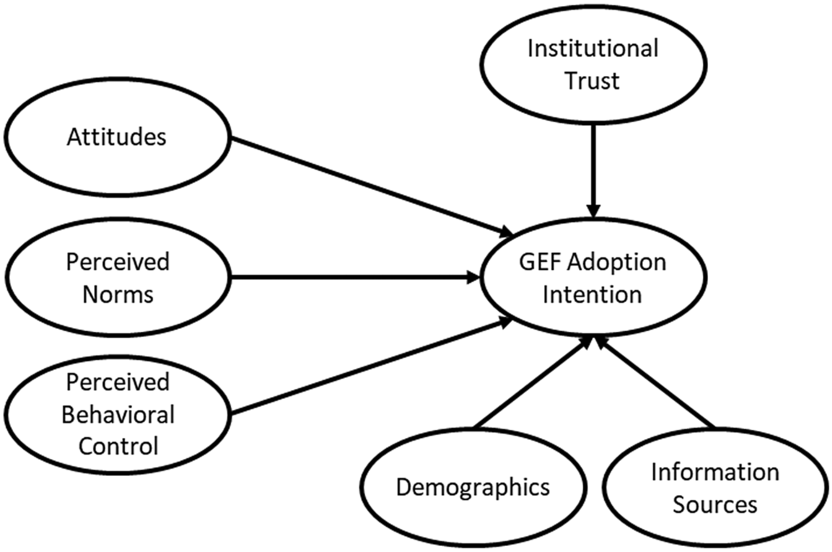

Figure 1. Conceptual Model of Gene-Edited Food Adoption Intentions Using the Theory of Planned Behavior and Instructional Trust.

relevant institutions, or that critical views among the public are simply caused by irrational emotions or a lack of certain scientific knowledge (Ahteensuu 2012; Wynne 2006).

The TPB is a parsimonious account of purposive action where observed behavior is a function of behavioral intentions that are based on social cognition theory (Ajzen 1991, 2012; Fishbein and Ajzen 2010; Perugini and Bagozzi 2001). In this study, adoption *intentions* are a person's willingness to accept or eat GEFs, seeing GEFs as beneficial, and not caring about GEF labels. Adoption intentions are hypothesized to be a function of one's *attitudes* about GEFs (e.g. food-related values and attitudes about the role of technology in society), *perceived norms* about adopting GEFs (e.g., potential risks or benefits, and what others in their peer group may think), and *perceived behavioral control* about adoption (e.g., ability to understand the technology, and ability to discern GEFs from non-GEFs). These are conditioned by background factors that include individual demographics, use of information sources about food, and trust in institutions overseeing GEFs (Lang, O'Neill, and Hallman 2003).

The literature defines institutional trust along four dimensions that includes competence, process, institutional capacity, and morality (Ahlquist and Levi 2013; Farrell 2009; Levi, Sacks, and Tyler 2009; Levi and Stoker 2000; Ostrom and Walker 2003). In the case of GEFs, relevant institutional actors include government food regulators, the agricultural biotechnology industry, consumer advocacy organizations, environmental groups, and university scientists. The *competence dimension* is whether the institution has the technical, legal, and social competence to understand and oversee the development of GEFs. The *process dimension* includes the ability of the institution to design and implement policies in a non-arbitrary manner; the ability to engage in fair and transparent decision-making; and an openness to competing views when making decisions about GEFs. The *institutional capacity dimension* includes checks and balances to ensure that actions are constrained, as well as the reliability and regularity of the institution's actions on GEFs. The *moral dimension* includes the institutions' moral obligation to act on behalf of the public; self-interest to act on behalf of the public; and the ability to make credible commitments with regards to GEFs.

Data and Methods

Sample

We conducted a survey on public attitudes and perceptions about plant-based GEFs. Data were obtained from a nationally representative web panel of n = 2,000 U.S. residents over 18 years of age, drawn from YouGov's National Omnibus Panel during the last 2 weeks of September 2020. The results have an observed margin of error of ±2.2 percentage points. The National Omnibus is a compensated opt-in survey panel comprised of 1.8 million U.S. residents who have agreed to participate. Panel members were recruited by several methods to help ensure representativeness of the panel population. Recruiting methods included web advertising, permission-based email contacts, partner sponsored solicitations, telephone contacts using random digit dialing, and mail contacts using random address selection (YouGov 2020). Data were weighted to match the demographic characteristics of the adult population based on the U.S. Census Bureau's 2018 American Community Survey. Our university's human subjects review board approved the GEF questionnaire and use of the National Omnibus.

Variables

We operationalized GEF adoption intentions using four *dependent variables* to measure publics' views on the benefits, acceptability, willingness to eat, and labeling of future GEF products made from crops. The first variable asked whether plant-based GEFs would directly benefit the respondent. The second asked whether foods containing gene-edited crops were considered acceptable to the respondent. The third asked if the person was willing to eat plant-based processed foods containing gene-edited crops (such as breads, pastas, snack chips, etc.). The last question posed whether the person thinks GEFs should be labeled. All dependent variables were measured on a 5-point Likert scale. A list of all questions and variable scales used in this study is provided in Appendix A in Supporting information.

Based on extant literature on food technology adoption, particularly the large body of work on GMOs, we selected the following covariates of potential GEF adoption (Lang 2013; Lang et al. 2003; Lang and Hallman 2005; Peters et al. 2007). These covariates link to the TPB and institutional trust conceptual model, presented in Figure 1. *Institutional trust* in GEF governance measures how the public views the institutional actors tasked with developing and overseeing this technology, which includes government food regulators, agriculture biotechnology companies, consumer advocacy organizations, environmental organizations, and university scientists and researchers. We conducted exploratory factor analyses (EFAs) on nine trust items for five institutional actors, as identified in the literature (Levi and Stoker 2000). Factor scales follow a z normal distribution with a mean of zero and variance of one. Two common trust factors were extracted with generally high dimensionality on each scale, except for one item that cross-loaded ("act in the public interest").

The *trust process scale* includes willingness to act in the public interest with regards to GEFs; honesty about the risks and benefits of the technology; ability to act in an open and transparent manner when discussing GEFs; whether the institution shares the respondents' values about the technology; ability to follow through on promises to oversee GEFs; willingness to address respondents' concerns; and the ability to act without bias in decisions about GEFs. All scale reliabilities are above $\lambda_4 = .89$ (greatest lower bound). The *trust competence scale* measures the scientific and technical competence to understand the risks and benefits of GEFs; ability to understand the social and ethical implications of the technology; and the willingness to act in the public interest. Reliabilities range between $\lambda_4 = .72$ and $\lambda_3 = .78$ (greatest lower bound and Cronbach's alpha, respectively), save for the agricultural biotechnology industry scale whose reliability is $\lambda_4 = .64$. Factor analysis results are presented in Appendix B in Supporting information.

For *attitudes* we measured values about food and the role of technology in society. We used EFAs to create three scales about the role values in food decisions. The *food choice product scale* included five items measuring the importance of food safety, cost, taste, and appearance on food decisions. The *food choice values scale* measured the significance of food ethics and beliefs; where the food came from; and organic certification. The single-item *food choice nutrition scale* determined the importance of nutritional content on food decisions. All factor scales had moderate reliability, ranging from $\lambda_4 = .63$ to $\lambda_3 = .68$. Next, the *science and technology societal benefit scale* factored six items rating disagreement on the following statements: the world would be better off without technology; leaders should stop funding science research; science creates more problems than solutions; scientists hide the truth; scientists do not value my concerns; and scientists exaggerate the truth. All items loaded onto a single factor scale with high reliability ($\lambda_4 = .88$). Details are presented in Appendix B in Supporting information.

Perceived norms are operationalized by two variables: whether people thought introducing plant-based GEFs foods poses a risk to the U.S. food supply, and whether they thought that GEFs benefit some people while putting others at risk. *Perceived behavioral control* variables included how much people personally care about the issue of GEFs; their self-rated understanding of GEFs; and whether they viewed GEFs as the same as non-GEFs. To understand the role of food *information sources*, we included the importance of friends and family, government agencies, food processors and manufacturers, the popular press, and social media as information sources about food risks and benefits. *Demographics* included the following: respondent's age, gender (coded as women), minority status (coded as non-white race or Hispanic ethnicity), educational attainment, and family income. Respondents also self-reported their physical health situation and their personal financial situation between poor and excellent. To control for pandemic effects, we included a question on whether COVID-19 has made life worse off or better off from 2 years ago. Also, we included an item on self-identified political affiliation between very liberal to very conservative and the importance of religion in the respondent's everyday life.

Statistical Procedures

We employed four separate ordinal regression models using a cumulative logistic distribution to predict each of the four dependent variables. We also included regional fixed effects to control for any variations and/or omitted variables across different parts of the United States, such as differences in state policy or culture, as is common in social science research (Verbeek 2012). Fixed effects were entered as nine regional dummy variables based on U.S. Census definitions, with the excluded region being the American Northeast. According to Greene (2011), ordinal model assumptions include low multicollinearity, linearity between logits and predictors, and independent residuals. Our model met those assumptions. However, all models violated the proportional odds assumption, which is likely due to the large sample size that biases χ^2 tests. Inspection of scatterplots revealed similar slopes across most dependent variables, suggesting type 1 or false-positive errors. The exception was the labeling variable which had unequal slopes. Equation 1 operationalizes the regression model, where **y*** are the adoption intention probabilities estimated by the model, $\boldsymbol{\alpha}$ the vector of intercepts for $j-1$ ordinal categories, **X** the matrix of independent variables with $\boldsymbol{\beta}$ cumulative logit regression slopes, and $\boldsymbol{\upsilon}$ the residuals following a Bernoulli distribution. Each case was assigned to a predicted ordinal category if the adoption probabilities fell within thresholds μ estimated by the model.

$$\mathbf{y}^* = \boldsymbol{\alpha} + \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\upsilon} \tag{1}$$

$$y_i = j \text{ if } \mu_{j-1} < {y^*}_i < \mu_j$$

We created scales to measure latent concepts and to reduce collinearity in the regression model. All EFAs employed principal components extraction and the number of factors was determined by eigenvalues, parallel analysis, Velicer's MAP test, and the comprehensibility of the factors (Loehlin 2004). Scales were created using the Anderson–Rubin factor score method, producing orthogonal or uncorrelated scores with a mean of zero and a unit variance of one (i.e. *z*-scores). All models exhibited factorable data ($KMO > 0.7$); high percent variance explained by the factors (about 65 percent to 70 percent); and high factor scale reliabilities (most lower bounds range from $\lambda_4 = .72$ to .90). Equation 2 operationalizes the EFA model, where **x** is the vector of observed indicator variables, $\boldsymbol{\nu}$ is the intercept/mean vector of **x**, $\boldsymbol{\xi}$ the vector of latent variables or factors, and $\boldsymbol{\Lambda}$ the factor loadings matrix linking the factors to the observed variables. Factors in $\boldsymbol{\xi}$ are orthogonal and measurement errors in $\boldsymbol{\delta}$ are uncorrelated. Results from the EFA models are presented in Appendix B in Supporting information.

$$\mathbf{x} = \boldsymbol{\nu} + \boldsymbol{\Lambda}\boldsymbol{\xi} + \boldsymbol{\delta} \tag{2}$$

Results

Institutional Trust and GEF Adoption Intentions

Table 1 provides a profile of people who are either likely or unlikely to adopt GEFs in the future by how much they trust institutions overseeing these foods. Most Americans are undecided on whether GEFs will benefit them directly (48.1 percent), with more saying no benefits over some benefits (38.1 percent vs. 13.9 percent). The public is more divided on

Table 1. Institutional Trust by Gene-Edited Food Adoption Intentions

	Direct Benefit		Acceptable		Willing to Eat		Want Labels	
Percentage	No	Yes	No	Yes	No	Yes	No	Yes
Percent no or yes	38.08	13.81*	30.32	29.19	32.84	28.82*	4.98	74.81*
Trust scientific/Technical competence								
Government food regulators	16.88	41.84*	15.97	39.22*	14.38	37.44*	32.36	23.36
Agric. biotech companies	28.74	60.68*	27.59	58.55*	28.35	55.34*	40.73	38.30
Consumer advocacy groups	25.89	33.50*	30.66	36.64*	25.22	37.59*	22.89	31.00
Environmental groups	29.29	43.52*	30.32	42.45*	29.67	42.70*	24.21	35.69*
University scientists	38.25	69.72*	39.61	72.22*	36.73	71.63*	45.74	51.28
Trust to understand social implications								
Government food regulators	21.02	37.08*	18.64	35.49*	18.78	32.84*	24.53	23.82
Agric. biotech companies	23.14	42.72*	24.27	40.02*	23.06	38.51*	39.47	27.38
Consumer advocacy groups	28.54	46.34*	32.33	45.25*	29.47	46.69*	37.54	35.24
Environmental groups	29.99	47.12*	32.44	47.57*	30.10	47.18*	38.56	36.96
University scientists	32.78	58.05*	34.88	59.88*	30.59	59.11*	37.50	41.17
Trust to act in public interest								
Government food regulators	20.69	44.56*	18.06	43.42*	17.51	40.10*	32.29	26.88
Agric. biotech companies	13.68	40.55*	11.64	32.30*	12.35	32.20*	24.41	20.30
Consumer advocacy groups	37.77	56.19*	43.04	56.81*	37.83	55.58*	40.54	46.91
Environmental groups	33.84	55.62*	35.43	54.61*	33.21	54.14*	35.90	43.27
University scientists	29.81	67.08*	30.65	63.95*	27.57	62.18*	48.27	41.13
Trust to be open and transparent								
Government food regulators	17.12	41.77*	13.72	38.19*	13.11	35.41*	23.84	22.77
Agric. biotech companies	11.90	31.79*	10.45	27.74*	12.49	26.49*	17.15	17.07
Consumer advocacy groups	30.43	47.47*	33.21	47.37*	30.67	48.17*	26.98	37.98*
Environmental groups	27.60	47.78*	29.02	46.33*	26.48	46.62*	35.05	35.84
University scientists	29.34	64.37*	30.14	62.69*	28.40	63.77*	38.29	40.91

Table 1. *Continued*

Percentage	Direct Benefit		Acceptable		Willing to Eat		Want Labels	
	No	Yes	No	Yes	No	Yes	No	Yes
Trust to address concerns								
Government food regulators	14.78	43.51*	12.45	35.84*	15.23	33.85*	27.44	21.43
Agric. biotech companies	11.01	32.60*	10.98	26.22*	12.79	25.58*	23.39	15.37
Consumer advocacy groups	31.02	47.03*	35.71	46.90*	32.19	47.58*	31.01	38.65
Environmental groups	27.20	45.52*	29.76	44.96*	28.66	44.91*	38.74	34.00
University scientists	24.01	52.15*	24.42	51.92*	24.42	49.16*	28.12	34.72
Trust to act without bias								
Government food regulators	15.22	34.39*	13.98	32.91*	13.17	31.34*	31.83	20.40
Agric. biotech companies	9.66	22.13*	8.80	21.29*	9.45	19.64*	17.69	13.02
Consumer advocacy groups	23.95	36.27*	27.70	35.15*	24.79	36.35*	18.52	29.94*
Environmental groups	20.48	32.42*	21.07	32.43*	20.16	33.85*	19.81	26.86
University scientists	23.64	54.21*	25.02	52.62*	24.27	53.20*	35.12	34.74

Note: Percentages reported, unless otherwise noted, for $n = 2{,}000$ adults in the U.S. in 2020.
*Significant difference between yes and no response at $p < .05$ using Games Howell test.

whether GEFs are acceptable and their willingness to eat them. About 40 percent are undecided, with about 30 percent each opposing or favoring acceptance and consumption. However, most Americans agree on one aspect of GEFs, and that is they want them to be labeled. Nearly 75 percent think these foods should be labeled, while only 5 percent do not. Demographic and social characteristics of those either likely or unlikely to adopt are presented in Appendix C in Supporting information.

In terms of trust, we find that Americans who see GEFs as beneficial, acceptable, and eatable highly trust university scientists at around 60 percent (see Figure 2). About 45 percent say they trust consumer and environmental advocacy groups. Trust in agricultural biotech firms that commercialize GEFs is low, with just over one-third saying they trust the biotech industry. Trust in government food regulators is also low, with trust ratings of 33 percent to 37 percent. Americans who want GEFs labeled have less trust in these institutions overall. However, even pro-label people had moderate trust in government, industry, and NGOs. In other words, favoring GEF labels did not indicate low trust in institutions, rather lower trust.

Table 1 presents results from specific measures of institutional trust by adoption intentions. We find likely adopters trust the scientific and technical competence of university scientists (over 70 percent) and the agricultural biotech industry (55 percent to 60 percent) to understand the risks and benefits of GEFs. However, adopters only place their trust in universities to understand the social and ethical implications of these new foods, with scores close to 60 percent. Likely adopters think that university researchers and consumer and environmental advocacy groups are the only institutions willing to act in the public interest in decisions about GEFs. The public also thinks that universities in particular, and to a lesser extent consumer and environmental advocates, will act in an open and transparent manner when discussing GEFs, and that these groups will take specific steps to address concerns the public has about these new foods. Despite this, Americans likely to adopt GEFs only trust university scientists to act without bias in decisions about these food products.

On the other hand, likely non-adopters hold far less trust in institutions, especially the biotech sector and government food regulators. Non-adopters tend to trust university scientists and advocacy groups, but even these trust levels are low. For example, those unlikely to adopt GEFs had trust ratings that were 28–30 percentage points lower than likely adopters. Non-adopters only trusted university researchers in their scientific competence to understand GEFs, posting the highest trust rating of all institutional actors, albeit at only around 37 percent. Non-adopters

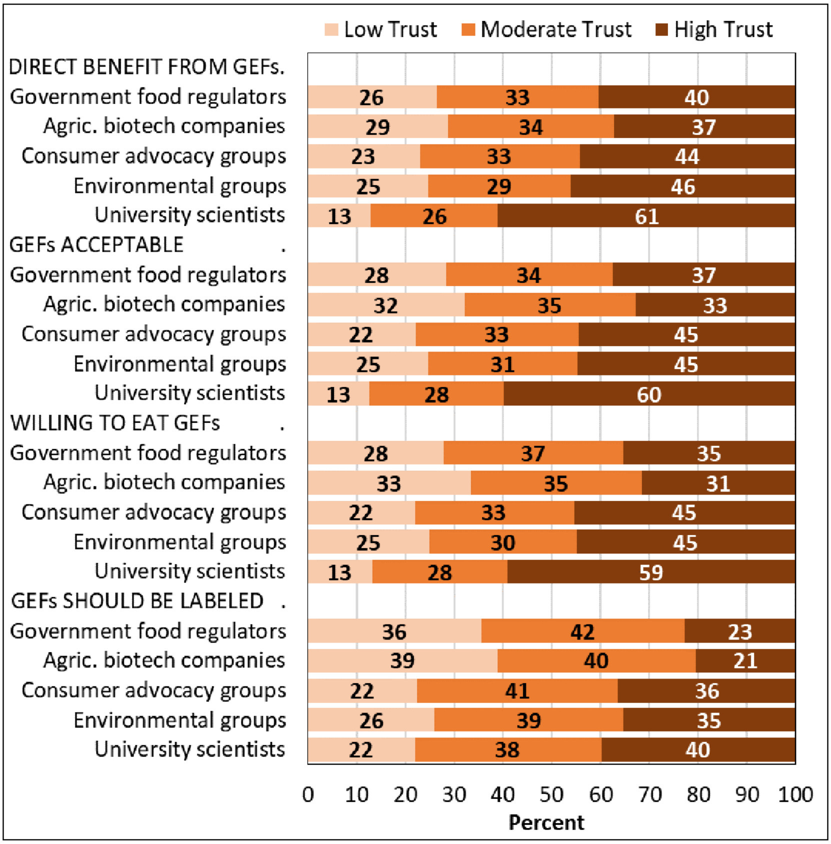

Figure 2. Ratings of Institutional Trust by Those Willing to Adopt Gene-Edited Foods for $n = 2{,}000$ Adults in the United States in 2020.

see consumer advocacy groups as the only ones trusted to act in the public interest and to address their issues and concerns about GEFs, but trust levels were only around 40 percent for the former and about 35 percent for the latter. This group of Americans does not highly trust any institution to understand the social and ethical implications of GEFs; to be open and transparent in discussions about GEFs; nor to act without bias in decisions about GEFs. Refer to Table 1.

Institutional trust matters when examining traditional adoption measures such as benefit, acceptability, and willingness to eat. However, we find very different results when it comes to opinions about labels on GEFs. We find almost no statistical differences in trust scores between those who favor or oppose labels. There are two related possibilities for this finding: one is that institutional trust has little to do with preference for labels on GEF products, and the other is that label preferences are driven by other factors such as perceived risk and demographics. Second and related, nearly all respondents favor labels (75 percent), indicating that most Americans desire to know what is in their food to make informed choices.

Who Benefits from GEFs?

Results of the ordinal regression models, presented in Table 2, show that the correlates of adoption account for 38.3 percent of the variance in whether people think GEFs will benefit them directly. People who are more likely to see a benefit are those who say GEFs are the same as non-GEFs (*OR* = 1.699); who report a better understanding of GEFs (*OR* = 1.324); and those who are better educated (*OR* = 1.105), increasing the odds of direct benefit by 69.9 percent, 32.4 percent, and 10.5 percent, respectively. This group also places a great deal of trust in university scientists and agricultural biotech firms, not only in their scientific and ethical competence, but also in their public engagement process (*OR* = 1.250–1.325). Pro-benefit people tend to view science and technology more favorably (*OR* = 1.149) and say nutritional content is important in food decisions (*OR* = 1.148). This group also follows the news closely (*OR* = 1.124) and gets their information about food risks and benefits from social media and government agencies (*OR* = 1.133 and 1.102, respectively).

Conversely, those less likely to see any direct benefit from GEFs strongly think these products pose a serious risk to the U.S. food supply (*OR* = .548), reducing the odds of direct benefit by 45.2 percent, the single strongest predictor in the model. Anti-benefit respondents think GEFs benefit some people while putting others at risk (*OR* = .831) and place great importance on their own ethics and beliefs when choosing food (*OR* = .863). Those with anti-benefit views trust the public engagement process of consumer advocacy organizations (*OR* = .862), but not their competence as this effect is non-significant. In terms of demographics, women are 34.8 percent less likely to perceive a direct benefit from GEFs, as are those in better health with a 13.1 percent reduction in odds.

Who Finds GEFs Acceptable and is Willing to Eat Them?

Two of the clearest indicators of adoption are acceptance of GEFs and willingness to eat them. Both models exhibit very good fit, accounting for 54.6 percent of the variance in acceptance and 47.9 percent in willingness to eat. Having a perceived better understanding of GEFs

Table 2. Predicting Public Intentions to Adopt Gene-Edited Foods (GEFs) for n = 1,980 Adults in the United States in 2020

	Direct Benefit			Acceptable			Willing to Eat			Want Labels		
	exp(b)	SE	*p*	exp(b)	SE	*p*	exp(b)	SE	*p*	exp(b)	SE	*p*
GEF institutional trust												
Government agencies, process (z)	1.119	(.062)	†	1.166	(.062)	*	1.164	(.061)	*	.851	(.064)	*
Government agencies, competence (z)	.966	(.056)		1.093	(.056)		1.065	(.055)		.906	(.059)	†
Ag. biotech industry, process (z)	1.325	(.063)	***	1.104	(.062)		1.068	(.061)		.905	(.065)	
Ag. biotech industry, competence (z)	1.232	(.055)	***	1.285	(.056)	***	1.134	(.054)	*	1.046	(.059)	
Consumer groups, process (z)	.862	(.072)	*	.823	(.073)	**	.848	(.071)	*	1.357	(.077)	***
Consumer groups, competence (z)	.936	(.064)		.874	(.065)	*	1.017	(.063)		1.074	(.067)	
Environmental groups, process (z)	.971	(.077)		.918	(.078)		.979	(.076)		.964	(.081)	
Environmental groups, competence (z)	.902	(.071)		.917	(.072)		.822	(.070)	**	1.197	(.074)	*
University scientists, process (z)	1.250	(.073)	**	1.439	(.075)	***	1.224	(.072)	**	.900	(.079)	
University scientists, competence (z)	1.263	(.065)	***	1.336	(.066)	***	1.316	(.064)	***	.919	(.069)	
GEF attitudes												
Food choices, product (z)	.949	(.053)		1.002	(.052)		1.003	(.051)		1.268	(.053)	***
Food choices, values (z)	.863	(.060)	*	.768	(.060)	***	.775	(.058)	***	1.003	(.061)	
Food choices, nutrition (z)	1.148	(.056)	*	1.134	(.055)	*	1.164	(.054)	**	.971	(.056)	
Pro science/technology (z)	1.149	(.062)	*	1.113	(.062)	†	1.248	(.061)	***	1.041	(.064)	

(Continued)

Table 2. *Continued*

	Direct Benefit			Acceptable			Willing to Eat			Want Labels		
	exp(b)	SE	*p*	exp(b)	SE	*p*	exp(b)	SE	*p*	exp(b)	SE	*p*
GEF perceived norms												
GEFs risk to U.S. food supply (1–5)	.548	(.056)	***	.328	(.059)	***	.405	(.056)	***	1.439	(.057)	***
Unequal benefits/risks of GEFs (1–5)	.831	(.059)	**	.744	(.062)	***	.817	(.059)	***	1.346	(.063)	***
GEF perceived behavioral control												
Personally care about GEFs (1–5)	1.046	(.046)		.796	(.046)	***	.892	(.045)	*	1.360	(.048)	***
Understanding of GEFs (1–5)	1.324	(.048)	***	1.532	(.049)	***	1.522	(.047)	***	.818	(.049)	***
GEFs same as non-GEFs (1–5)	1.699	(.054)	***	1.431	(.054)	***	1.524	(.053)	***	.672	(.056)	***
Food information sources												
Time spent following the news (1–4)	1.124	(.049)	*	1.156	(.049)	**	1.192	(.048)	***	1.250	(.050)	***
Family/friends (1–5)	1.002	(.043)		.899	(.043)	*	.934	(.042)		1.031	(.045)	
Government agencies (1–5)	1.102	(.047)	*	1.102	(.047)	*	1.018	(.046)		.989	(.049)	
Food company (1–5)	.995	(.044)		1.011	(.044)		1.060	(.043)		1.141	(.046)	**
Popular press (1–5)	.992	(.047)		1.028	(.047)		.961	(.046)		.944	(.048)	
Social media (1–5)	1.133	(.046)	**	1.073	(.046)		1.093	(.045)	*	.828	(.048)	***
Demographics												
Age (years)	.997	(.003)		.990	(.003)	***	.986	(.003)	***	1.013	(.003)	***
Women (ref = men)	.652	(.094)	***	.766	(.094)	**	.833	(.092)	*	1.173	(.097)	†
Minority (ref = white non-Hispanic)	1.019	(.102)		.921	(.102)		.842	(.099)	†	.945	(.104)	
Educational attainment (1–6)	1.105	(.034)	**	1.050	(.034)		1.041	(.033)		.969	(.035)	
Family income (1–16)	1.015	(.016)		1.028	(.016)	†	1.022	(.016)		.995	(.017)	
Health situation (1–5)	.869	(.050)	**	.884	(.050)	*	.812	(.049)	***	1.091	(.052)	†
Financial situation (1–5)	1.100	(.051)	†	1.097	(.051)	†	1.136	(.050)	*	1.058	(.052)	

Table 2. ***Continued***

	Direct Benefit			Acceptable			Willing to Eat			Want Labels		
	exp(b)	SE	*p*	exp(b)	SE	*p*	exp(b)	SE	*p*	exp(b)	SE	*p*
Impact of COVID, worse–better (1–5)	1.002	(.056)		1.098	(.056)	†	1.022	(.054)		.939	(.057)	
Politics, liberal–conservative (1–5)	.938	(.051)		1.016	(.050)		.941	(.049)		1.165	(.052)	**
Importance of religion (1–4)	.952	(.043)		.920	(.043)	*	.927	(.042)	†	1.029	(.044)	
Intercepts and controls	*b*	*SE*		*b*	*SE*		*b*	*SE*		*b*	*SE*	
Intercept [response = 1]	−2.454	(.512)	***	−6.078	(.527)	***	−5.329	(.511)	***	−1.751	(.543)	**
[response = 2]	−.540	(.508)		−4.530	(.519)	***	−3.571	(.503)	***	−.743	(.530)	
[response = 3]	2.533	(.513)	***	−1.811	(.510)	***	−1.173	(.496)	*	1.449	(.526)	**
[response = 4]	4.420	(.527)	***	−.185	(.510)		.649	(.498)		3.107	(.530)	***
Regional fixed effects	Y			Y			Y			Y		
Model fit												
Goodness of Fit Test *Deviance* $\chi^2_{(7869)}$	4326.424			4475.812			4733.769			4138.966		
Proportional Odds Test $\chi^2_{(129)}$	220.181		***	269.214		***	229.935		***	418.467		***
$pR^2_{Nagelkerke}$	.383			.546			.479			.328		

Note: exp(b) = odds ratio. b = logit. SE = standard error.
†$p<.10$, *$p<.05$, **$p<.01$, ***$p<.001$.

increases the odds of acceptance and consumption by about 52 percent, while the belief that GEFs are the same as conventional non-GEFs increases acceptance by 43.1 percent and consumption by 52.4 percent. This group highly trusts both the competence (*OR* about 1.320) and engagement process (*OR* = 1.224–1.439) of university scientists; the competence of agriculture biotech firms (OR = 1.134–1.285); and the engagement process of government food regulators (*OR* about 1.165). Trust has a greater affect on acceptance, but a weaker one on willingness to eat. This suggests a disconnect between abstract and passive adoption of GEFs (i.e. acceptance) versus tangible and active adoption (i.e. consumption). Adopters are also more likely to make food decisions based on nutritional content, increasing acceptance by 13.4 percent and consumption by 16.4 percent. Despite these similarities, differences exist. Those willing to eat GEFs are far more positive about the role of science and technology in American society than those who find the technology acceptable (*OR* = 1.248 vs. 1.113). Also, those more likely to consume are more satisfied with their financial situation than those who only accept GEFs.

On the other hand, unwillingness to accept and eat is largely driven by concerns that GEFs pose a serious risk to the food supply, decreasing odds of adoption by 32.8 percent and 40.5 percent, respectively. To a lesser degree, the unwilling group values their beliefs when making food choices (about *OR* = .772), and they see GEFs as carrying unequal risks and benefits (*OR* = .744–.817). Perhaps because of this, the GEF issue is personally important to this group (*OR* = .796–.892). Adoption skeptics highly trust the public engagement process of consumer advocacy groups (*OR* = .823–.848), but there are differing opinions as to who is more competent. The unaccepting place more trust in the competence of consumer groups (*OR* = .874), while the unwilling to eat trust the competency of environmental organizations (*OR* = .822). As for demographic differences, women are 23.4 percent less likely to accept GEFs, but only 16.7 percent less likely to consume them. Being in perceived better health reduces acceptance by 11.6 percent and consumption by 18.8 percent. People who are older, more religious, and who live in the south Atlantic region (states of Maryland and West Virginia down to Florida) are also less likely to adopt GEFs. Racial and ethnic minorities are less willing to eat GEFs, although the effect is only marginally significant.

Who Wants GEFs Labeled?

The reasons why people think GEFs should be labeled are less clear, as model fit is the lowest of the four adoption outcomes (pR^2 = .328). One reason for poor fit is there may be less variance to explain. For example, most Americans agree on labels, with 46 percent strongly agreeing and 29 percent agreeing. Furthermore, inspection of regression slopes for each ordinal category shows sizable differences, indicating the model could not estimate a common slope. Despite these limitations, there are some insights that can be gained from the model. Americans are more likely to support labels if they if they think GEFs pose a major risk to the food supply (*OR* = 1.439); if they strongly care about the GEF issue (*OR* = 1.360); and if they think GEFs have unequal risks and benefits (*OR* = 1.346)—increasing label supports by 43.9 percent, 36.0 percent, and 34.6 percent, respectively. People who tend to make food decisions primarily on the qualities of the product, such as safety, cost, taste, and appearance, are 26.8 percent more likely to want labels (*OR* = 1.268). This is a very different finding from the other adoption outcomes, where food values and nutrition are important. Most favoring labels get their information about food benefits and risks from food processors and manufacturers (*OR* = 1.141). Pro-label individuals only trust the public engagement process of consumer advocacy organizations (*OR* = 1.357), and they only trust environmental groups on their technical and ethical competence to oversee GEFs (*OR* = 1.197). Demographically, those who support GEF labels are older, news followers, political conservatives, and women.

For Americans who do not think GEFs should be labeled, the strongest predictor is seeing GEFs as identical to non-GEFs (*OR* = .672), decreasing support for labels by 32.8 percent. Other factors decreasing support for labels include greater self-reported understanding of GEFs (*OR* = .818) and use of social media to obtain food information (*OR* = .828). In addition, Americans who trust the competence and engagement process of government regulators are less likely to see the need for labels on GEFs.

Discussion

We discuss our findings by answering the two research questions posed at the beginning of the current study. First, what do Americans think about the potential benefits, acceptability, willingness to eat, and labeling of foods made with gene-edited crops? We find that very few Americans (only 14 percent) see a personal direct benefit from GEFs, with nearly half remaining undecided. About 29 percent of the public finds GEFs acceptable and would be willing to eat these foods, while around 33 percent find them unacceptable and would avoid eating GEFs. In short, the American public is largely undecided about GEF food adoption at the present time, with rates ranging between 40 percent and 50 percent. However, the public clearly supports labeling GEFs, with 75 percent in favor. In general, older people view GEFs more unfavorably than younger cohorts. In addition, nearly 60 percent of women see no direct benefit of GEFs, find them unacceptable, and are unwilling to eat them.

Second, is the potential adoption of GEFs dependent on the public's trust in the institutions tasked with overseeing their development and regulation? We find that trust is a major driver of adoption intentions. However, trust had a minimal effect on the public's desire for labels, likely because the vast majority favor them. Likely adopters place greater trust in university scientists, government food regulators, and the agricultural biotechnology industry to properly develop and oversee GEFs. Trust in these institutions likely stems from pro-science orientations and lack of concern about GEFs. Levels of process trust (acting in the public interest, no bias in decisions, honesty, transparency, etc.) for government and industry is nearly double that for non-adopters, as is trust in the technological competence of the biotech industry. Adopters strongly trust university scientists on all aspects of trust, but only trust the biotech industry in their technical competence. Adopters also trust consumer advocacy groups to act in the public's interest in decisions about GEFs; be open and transparent in discussions; and be willing to take specific steps to address their concerns about GEFs.

By contrast, those unlikely to adopt place far less trust in all institutional actors involved with GEF oversight, especially government and industry. Instead, this group places their trust in consumer and environmental organizations. Besides trusting these groups to better understand the social and ethical implications of GEFs, non-adopters also trust them to act in the public interest and without bias and be more transparent and honest when discussing the risks and benefits of GEFs. Differences in trust are associated with ethical concerns about GEFs and anti-technology orientations. Non-adopters see GEFs as high risk and unethical. About 50 percent of non-adopters think GEFs pose a major risk to the nation's food supply (vs. 10 percent for adopters), and about one-third think GEFs provide unequal benefits and risks to certain segments of society (vs. 15 percent for adopters). For this group, GEF social concerns are of great importance.

What drives opinions for labeling of GEFs is different from that of adoption. Counter to what is found for adoption, trust in government food regulators, trust in the biotech industry, and pro-technology values play minimal roles in anti-label attitudes. Our findings suggest this group is not opposed to labels per se; rather, they see no need to label a GEF because they view GEF as similar to conventional foods. By contrast, those supporting labels ground their opinions in institutional trust and values, similar to what is found for non-adopters of GEFs. Label supporters see GEFs as posing risks to the food supply and people, and they have less trust of government and industry. One surprising finding is that pro-label Americans say the characteristics of food products are very important in their food choices. The most important characteristics among pro-label people are food taste (72 percent) and safety (70 percent), while secondary considerations are food cost and appearance (around 35 percent). This suggests many Americans have concerns about the safety and taste of GEFs over conventionally bred foods and are less concerned about the price and visual appeal of future GEFs.

Policy Implications and Conclusion

Advancements in gene editing promise to deliver new agricultural and food products in the near term. This will likely create public debates on whether Americans will or should accept or reject these foods and policy debates on how these new foods should be regulated or labeled. Failure to understand public perceptions about GEFs and the right to be informed about them may lead to a public backlash against these products, potentially repeating the contentious debate about GMO foods (Doxzen and Henderson 2020). We find that adoption intentions of GEFs generally hinge on strong institutional trust, especially in university scientists, and pre-existing pro-technology values, as opposed to tangible qualities such as the cost, taste, and appearance of these new foods.

At present, Americans can be classified into three relative groups based on their current adoption intentions. On one end of the continuum, about 29 percent of the American public is likely to adopt GEFs. This group possesses pro-technology values and highly trusts university scientists on all aspects of GEF oversight, ranging from their technical and ethical competence to their engagement process with the public. Trusted consumer and environmental groups can play a role by fostering transparency with the public and being a conduit to address concerns about GEFs.

On the other end, a nearly equal number are likely non-adopters who oppose GEFs on ethical and moral grounds, viewing GEFs as a risk to the food supply and providing unequal benefits and risks in society. This group also distrusts current regulatory systems in favor of consumer and environmental groups. Non-adopters only trust the technical competence of universities and only trust consumer advocacy groups on their willingness to act on the public's behalf and to address concerns. Apart from these two actors, non-adopters think no institution can be highly trusted to understand ethical implications; to be open and transparent; nor to act without bias in the case of GEFs.

Most Americans (41 percent) fall into the "undecided middle." They are uncertain about the risks and benefits of GEFs. Our findings suggest that many in the undecided middle have social concerns about this new technology, but they are also receptive to the potential benefits. In the future, the "undecided middle" may shape the future trajectory of public adoption or rejection of GEFs (Barberá et al. 2019; Bromley-Trujillo and Poe 2020). As more GEFs enter the marketplace and as consumers become more aware of the technology, the undecided middle will need to make decisions on whether to purchase and consume GEFs.

We find that institutions can play a critical role in future GEF adoption decisions. In particular, universities are highly trusted actors. Through their research and critical assessments, universities can contribute to building public confidence in the technical and ethical aspects of GEFs, as well as fostering public trust in the process of GEF development as universities are viewed as transparent and unbiased. This will require collaboration among plant scientists, social scientists, and ethicists at research universities. Consumer advocacy groups can play a pivotal role in building trust in the process of overseeing GEFs, as the public thinks such groups are more willing to act on behalf of the public and to take actions to address public concerns. By contrast, the public views government food regulators and the biotech industry as being less open and transparent in decisions about GEFs; as being less willing to act in the public interest; and as being less able to understand the social and ethical implications of GEFs. Our findings highlight a concerning tension: Many Americans do not trust government in their ability to regulate and oversee GEFs, yet only the government has the statutory authority to do so. This suggests that public trust in GEF could potentially fostered by a tripartite governance consisting of university scientists, relevant advocacy groups, and government regulators.

Our most significant finding, however, is that although Americans are divided on whether to accept and eat GEFs, the public clearly desires to see GEFs labeled. This preference for labels aligns with emergent research findings among segments of European populations (Ferrari et al. 2021; FSA 2021). Over 75 percent favor labeling of GEFs, albeit for a variety of values-based and safety concerns. Institutional trust has little impact on whether Americans favor or oppose GEF labels, suggesting other values and attitudes are at play. This finding reflects that of Cummings, Chuah, and Shirley (2018) regarding public desires for labeling of nanotechnology-enabled food products, where some consumers viewed the labels as "a right to be informed," while others found the labels to serve as a "do not buy caution."

The U.S. public's desire for GEF labeling highlights an important policy tension: most GEFs in development will not require a disclosure label. The current bioengineered food label, enacted by the federal government in 2016 and implemented in 2022, does not apply to cisgenic GEFs as they do not contain genes from multiple species (Federal Register 2018). This may signal an opportunity to address concerns through non-governmental or quasi-public labeling initiatives. However, such systems need to be grounded in the science and ethics of GEF development; be open and transparent in the deliberative process; and be usable by biotechnology and food industries in terms of cost and implementation. Ultimately, non-governmental labels may be more trusted by some segments of the public than current labels issued by the federal government.

The public's desire for GEF labels also aligns with Bartkowski and Baum's (2019) argument for an "exit-voice framework" of GEF governance. Labels would allow consumers dissatisfied or mistrustful of GEF technology and/or GEF vested institutions the ability to identify GEFs and then choose alternative foods that align with their food system values. In other words, labels offer consumers an "exit" from GEF if they desire it (Bartkowski and Baum 2019) because labels serve as one type of food informational cue valued by consumers (Kolodinsky et al. 2019).

The major limitation of our study is that gene editing is a new technology, and many people may not know how to respond or may not have formed any opinions about GEFs yet. Preferences and opinions are likely to change in the future as more GEF products come into the market. Lack of awareness may also cause people to conflate GEFs and GMOs, although our questionnaire was designed to minimize potential confusion by explaining the differences throughout. A second limitation is the possible impact of COVID-19 on the results, as the data were collected between the summer surge in 2020 and the winter surge in 2020–2021. It is likely respondents were more conscious of their health and financial status at this stage in the pandemic, but anti-technology views exacerbated by vaccine hesitancy were unlikely to be an issue since vaccines were not yet available in September 2020. The last limitation is that this study, and others using the TPB, do not model indirect effects. This is a significant gap in the adoption literature, as most studies only use direct effect models (see Lu et al. 2022 for a review). For example, Gao and Arbuckle (2022), Roesch-McNally et al. (2017), and Ulrich-Schad et al. (2016) all show conceptual models with indirect effects, but only model direct effects. Future work should address this modeling gap to see if prior results hold. The results of our study should be considered an important step toward better understanding public perceptions of GEFs in the United States.

AUTHOR CONTRIBUTIONS. S.A. Lindberg: Conceptualization, Writing—original draft, Writing—review and editing. **D.J. Peters**: Formal analysis, Methodology, Writing—original draft, Writing—review and editing. **C.L. Cummings**: Conceptualization, Writing—review and editing.

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ENDNOTE

[1] Gene-edited DNA modifications can vary in complexity. "GEF" in this paper refers to the simplest and currently most common type of edits, classified as SDN-1, which change a specific part of the DNA in a single organism. However, more complex DNA changes and transgenic changes are also possible. See CAST 2018 for information on types of edits and EU-SAGE 2022 for a database on GEF research applications in plants.

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