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Show me the benefits! Determinants of behavioral intentions towards CRISPR in the United States

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Abstract: Novel plant-breeding techniques such as CRISPR are potentially key tools in the transition to a more sustainable food and agricultural system. For such potential to be realized, greater attention is required to outstanding questions related to public and societal acceptance. The current research thus employed a structural model to elucidate the interplay of factors that influence behavioral intentions towards CRISPR, for a sample of 158 individuals in the United States. By means of partial least-squares structural equation modeling (PLS-SEM), we established the predominance of perceived benefits vis-à-vis perceived risks for explaining behavioral intentions, along with the indirect effects of food technology neophobia, social trust, and environmental worldviews, all transmitted through perceived benefits – and less so, perceived risks. Overall, this offers key insights regarding behavioral intentions towards CRISPR food, highlighting how consumers may be more interested in understanding potential benefits than being dissuaded about any possible risks and signaling ways in which perceptions of benefits might be influenced. Indeed, the strength of the relationship between perceived benefits and behavioral intentions offers a counterpoint to arguments that benefits are not relevant for acceptance as well as marks a potential point of distinction between GM and GE food.

Keywords: behavioral intention; benefit-risk perception; consumer survey; CRISPR; food technology neophobia; structural equation modelling

JEL codes: D12; D91; Q16; Q18; D83

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1 Introduction

Novel plant-breeding techniques (NPBTs) are key tools in the transition to a sustainable food and agricultural system. In view of global challenges for sustainable development like climate change, population growth, and food and nutritional insecurity, many authors argue that such innovations in plant breeding are needed now more than ever (Sander and Joung, 2014; Hickey et al., 2019; Zaidi et al., 2019; Wurtzel et al., 2019; Anders et al., 2021). To this end, the greater pace, precision, and efficiency of NPBTs could enable plant breeders to develop crop varieties suited to the current social and environmental circumstances (Schaart et al., 2016; Bailey-Serres et al., 2019; Wurtzel et al., 2019; Carter and Mankad, 2021).

Discussion of the potential of NPBTs is increasingly focused on CRISPR-Cas9, first discovered in 2012 and winning the 2020 Nobel Prize in Chemistry (Jinek et al., 2012; Ledford, 2015). CRISPR, or clustered regularly interspaced short palindromic repeats, are 'spacer' sequences repeating in the genetic code of bacteria and have been identified as reflecting the genetic record of its past encounters with invading viruses. When combined with an enzyme such as Cas9 that acts as a "cellular scalpel" and a "guide RNA" to target a specific site, it becomes possible to make double-strand and single-strand cuts to DNA. and thereby facilitate gene editing (e.g., Zhang et al. 2014; Jiang et al. 2015). Among other advantages, CRISPR is hailed for its greater combinatorial power, i.e., to make many gene tweaks at the same time, quicker pace, increased ease of use, and radically lower costs (Ledford, 2015). Such advantages can support scientific research and development, human medicine, and environmental conservation, though we focus on those related to agriculture and food production in the present study, i.e., with CRISPR as a tool for precision crop breeding (Hickey et al., 2019; Khan et al., 2019; Zhang et al., 2020; Lin et al., 2020; Li et al., 2021). So far, applications of CRISPR in the pipeline or on the market include: crops (rice, wheat, maize, beans, tomatoes, cocoa, lettuce, potatoes, etc.) with greater tolerance to abiotic and biotic stresses like diseases, pesticides, drought, heat, and soil salinity (Martín-Pizarro and Posé, 2018; Eshed and Lippman, 2019; Qi, 2019; Qaim, 2020); non-browning mushrooms (Waltz, 2016); potatoes (González et al., 2020) and apples (Maxmen, 2017); strawberries more nutritious, sweeter, and longer-lasting (Martín-Pizarro et al., 2019); tomatoes which are seedless (Ueta et al., 2017) and more resistant to harmful pathogens (Nekrasov et al., 2017). With this in mind, Qaim (2020) has stressed the potential of CRISPR to redress shortcomings of the Green Revolution and to enable the agri-food sector to keep up with the risks of a rapidly changing climate (see also Bain et al., 2020).

For the potential of CRISPR to be realized, however, greater attention is required to outstanding questions related to public and societal acceptance (Anders et al., 2021; Scheufele et al., 2021), especially given the disruptive potential of such technologies for legal frameworks and societies (Bain et al., 2020; Purnhagen and Wesseler, 2021; Siebert et al., 2021). Here we highlight the need for insights into those determinants most germane to consumer attitudes and behavioral intentions of CRISPR. At first, the literature did not attempt to distinguish CRISPR from other NPBTs like RNAi and TALENs; instead, a contrast was drawn between cisgenic (or intragenic) and transgenic approaches to food production (i.e., gene transfer between crossable and non-crossable species, respectively) to determine if the two were perceived to be different from one another and in relation to conventional breeding. In this vein, NPBTs have been identified as a way to address the public concern and backlash to genetically modified (GM) food, e.g., on introduction of foreign DNA, dominance of multinational firms, lack of interest in specialty and horticultural crops (Lucht, 2015; Ishii and Araki, 2016; van Hove and Gillund, 2017; Lusk et al., 2018; Bartkowski et al., 2018; Bain et al., 2020). In recent years, various empirical studies focusing on CRISPR have emerged, each offering insights on consumer attitudes or behavioral intention in different contexts (Farid et al., 2020; Ferrari et al., 2021; Gatica-Arias et al., 2019; Marette et al., 2021a, 2021b; McFadden and Smyth, 2019; Muringai et al., 2020; Shew et al., 2018; Son and Lim, 2021; Yang and Hobbs, 2020; Ortega et al., 2022).

This literature could be usefully extended in two directions. First, research has so far attempted to identify key factors that directly impact consumer acceptance of CRISPR, while leaving the interplay between different factors, most notably, when it comes to risk and benefit perceptions, and/or distinguishing between the direct and indirect effects to future research. Second, while knowledge and information provision have received sizable attention, other factors like social trust, environmental worldviews, and food technology neophobia – all relevant for exploring acceptance of novel food technologies (e.g., Kamrath et al., 2019; Siegrist and Hartmann, 2020) – are yet to receive much interest.

Accordingly, this article develops a novel structural model to elucidate the interplay of factors that influence behavioral intentions towards CRISPR. For this purpose, we extended the model put forward by Siegrist (1999, 2000) to understand acceptance of gene technologies, given both its reliance on perceived risks and benefits as core factors and its previous application to other gene technologies. By means of partial least-squares structural equation modeling (PLS-SEM), we established the predominance of perceived benefits vis-à-vis perceived risks for explaining behavioral intentions towards CRISPR, along with the significance of indirect effects of food technology neophobia, social trust, and environmental worldviews, all transmitted through perceived benefits – and less so, perceived risks. Overall, this research offers crucial insights on the behavioral intentions of consumers towards CRISPR food, notably, by highlighting how consumers may be more interested in understanding its potential benefits than being dissuaded about any possible risks.

2 Theoretical framework and hypotheses development

2.1 Consumer and public acceptance of CRISPR food

With CRISPR garnering media attention and becoming more familiar, a handful of studies have set their sights squarely on examining this technique. Attempting to wrestle with the challenges posed by CRISPR, Ishii and Araki (2016) endorsed careful consideration of potential off-target mutations and avoiding the more complex forms of genome editing at first – in order to cultivate trust and acceptance. Similarly, Bartkowski and Baum (2019) applied the exit-voice framework of Hirschman to clarify the diverse expressions of dissatisfaction with NPBTs that exist, seeking to make sense of the complex, multifaceted criticisms put forward by consumers and the public at large. Moreover, Scheufele et al. (2021) have provided a much-needed inquisition regarding the what, how, and why of effective public engagement on "CRISPR and beyond". Nonetheless, while such articles offer insights on the contours of acceptance of CRISPR and propose valuable solutions to improve communication and public understanding, they are less clear on the details and dynamics of behavioral intentions towards purchasing and consuming such products.

Reflecting the nascent status of CRISPR, especially in the context of food, research into public perceptions of the technology and its possible applications is limited but growing. In general, consumers appear to be more dismissive of transgenic approaches, resulting in a need for higher discounts and lower willingness-to-pay, relative to conventional food, especially where no other benefits are thus provided (Delwaide et al., 2015; De Steur et al., 2015; Shew et al., 2016, 2017; Rousseliére and Rousseliére 2017; Edenbrandt et al., 2018; De Marchi et al., 2019, 2021; Inbar et al. 2020; Muringai et al., 2020; Beghin and Gustafson, 2021; Son and Lim, 2021; Götz et al., 2022; Ortega et al., 2022). One explanation is that gene-edited (GE) food is seen as more natural than its GM counterpart, removing a cause for concern (Muringai et al., 2020; Yang and Hobbs, 2020; Busch et al., 2021). Another is tied to the novelty of CRISPR itself, such that consumers do not necessarily link it to the controversial status of GM and prove more open and responsive to information (Yang and Hobbs, 2020; Busch et al., 2021; Strobbe et al., 2023). Here we point to the finding from Gatica-Arias et al. (2019) that, while knowledge of CRISPR (in Costa Rica) is presently low, potential acceptance appears to be high, especially if benefits for the environment and economy are stressed. Similarly, despite concerns CRISPR food may be rejected, a multi-country study by Shew et al. (2018) revealed that more individuals were willing to consume GM and CRISPR food, revealing a broadly favorable attitude to CRISPR. Marette et al. (2021a, 2021b) also pointed to a reason for optimism around GE acceptance even in a European context, whose consumers are often seen to be among those most rejecting of GM food (e.g., Gaskell et al., 2011). As such, limited knowledge of CRISPR suggests that consumer attitudes and behavioral intentions may be less entrenched.

That being said, past research does not indicate that CRISPR-edited and conventional food are perceived as equally desirable (e.g., Shew et al., 2016; Britton and Tonsor, 2019). If anything, the general takeaway is that CRISPR food achieves parity only under certain conditions and, notably, if potential benefits are sufficiently clear. For instance, Edenbrandt et al. (2018) revealed a slight preference for cisgenic bread only if coupled with reductions in use of pesticides, and if compared to traditional bread made using pesticides, while Ortega et al. (2022) demonstrated positive impacts on acceptance of GE rice and GE pork if gene editing was used, respectively, to address cadmium concentration and African swine fever. In their study on non-browning GE apples, Marette et al. (2021a) also revealed that such produce no longer required a discount among those with positive attitudes towards novel food innovations and technologies once the beneficial aspects (for human health and environment) were stressed. Though a proportion of participants fundamentally "boycotted" the purchasing of GE (and GM) apples in the experiment, information about the prospective benefits proved influential for a large segment of consumers. On this point, Yang and Hobbs (2020) revealed that those with more positive attitudes on science and technology were more favorable towards CRISPR food, while Muringai et al. (2020) found participants who believed technology makes the world better were more likely to be convinced of the benefits and overall value of GM/GE potatoes. In their study on GE/GM apples, Rousseliére and Rousseliére (2017) also excavated a useful distinction, whereby those with general interest in science or biotechnology – or a background in one of these areas (see Ferrari et al., 2021) – were more likely to accept GE products, while individuals who expressed interest in the environment were more skeptical. The relevance of pro-environmental attitudes is also highlighted by Shew et al. (2018), who however found agreement with the potential for GM/CRISPR rice to "help solve environmental problems" to be a crucial driver of willingness to consume. Also, Ferrari et al. (2021) revealed that attitudes towards GE food among young generations of Belgian and Dutch consumers were negatively impacted by environmental worldviews, lending support to findings by Rousseliére and Rousseliére (2017). Further research is therefore needed around the interplay of environmental worldviews and attitudes and intentions towards CRISPR.

Not all benefits are equally important or persuasive to consumers however, though the order of preference seems to vary by context and application. For instance, Muringai et al. (2020) found higher consumer interest (in GE/GM potatoes) where health instead of environmental benefits were emphasized. Similarly, Marette et al. (2021a) have contended that an emphasis on tangible consumer benefits (i.e., non-browning apples) is more persuasive than indirect benefits to either the environment or pest resistance (e.g., Rousseliére and Rousseliére, 2017; De Marchi et al., 2019). Furthermore, a set of cross-country surveys from Busch et al. (2021) showed significant differences across countries – with GE applications viewed more positively by Italians and Americans than Austrians and Germans – and by type of application. Notably, they revealed that, across all countries, use of genome editing to foster disease resistance in humans was seen most positively, followed by disease resistance in plants, then animals. Conversely, the aim of improving product quality (to produce allergen-free milk) or increasing muscle growth in cattle were deemed least "right to do". As such, applications targeting animals seem to be viewed less positively than those for plants and animals, and moreover those for purposes of product quality or production quantity seem especially fraught – somewhat contradicting Marette et al. (2021a).

Another vein of research has given greater consideration to the importance of the perceptions of the risks and benefits of CRISPR for understanding acceptance of GM and gene technologies (Sjöberg, 2000; Weber et al., 2002; Scott et al., 2016; Kamrath et al., 2019; Strobbe et al., 2023). Indeed, for a range of applications such as GM food (De Steur et al., 2014), nanotechnology (Kim et al., 2005), and synthetic biology (Akin et al., 2017), the ratio of perceived benefits to perceived risks is one of the strongest predictors of support. When it comes to CRISPR and GE food, on the other hand, such perceptions – along with their interplay with other factors – have received less attention. Notable exceptions include Yang and Hobbs (2020), who found lower levels risk perceptions impacted acceptance, and Ferrari et al. (2021), which linked the degree to which individuals were positive of the ratio of benefits to risks to disagreement with the belief that GE food should have its own label. Lastly, Farid et al. (2020) showed that perceived benefits had a significantly positive impact on willingness to buy GE food for young Japanese consumers, while perceived risks had a significantly negative effect. One explanation for a limited focus on risk and benefit perceptions may be the broader interest in how much knowledge (or familiarity) individuals have with GE (and GM) food. In general, those more knowledgeable are more likely to accept GE food (Shew et al., 2018; Ferrari et al., 2021; Busch et al., 2021; Son and Lim, 2021). Interestingly, rather than taking knowledge as a determinant in its own right, Kato-Nitta et al. (2019) employed differences in scientific knowledge as a way to categorize individuals as an expert in molecular biology, expert in another field, or as a member of the lay public. Significant differences between the groups in terms of risk, benefit, and value perceptions of GE and GM food were subsequently established, with the experts from molecular biology featuring higher benefit and value perceptions as well as lower risk perceptions. In consequence, understanding the relevance of perceived risks and benefits for intentions and the acceptance of CRISPR food stands out as a crucial gap deserving of further attention.

2.2 Outlining a structural model for behavioral intentions towards CRISPR

The foregoing insights highlight a need for an in-depth analysis of the direct and indirect effects on behavioral intentions towards CRISPR. Already, research has identified differences in terms of how GM and CRISPR are perceived, and the overlapping relevance of several determinants, like environmental worldviews, social trust, and food technology neophobia. However, given the absence of structural modelling frameworks in the CRISPR literature (with Farid et al., 2020 as an exception), prior research is yet to sufficiently explore the interplay among explanatory factors and how this ultimately influences attitudes and intentions, which serve as the principal focus of such analysis (Kamrath et al., 2019). Hence, it is crucial to determine, first, the extent to which the effects of certain factors occur indirectly and directly and, second, how such factors relate to one another, rather than to only intentions and acceptance. Furthermore, in view of the limited attention to perceptions of risks and benefits of CRISPR-edited foods, specific emphasis is given to investigating the relevance of these factors by means of a more structural approach.

For this reason, we extended the model used by Siegrist (1999, 2000) to understand acceptance of gene technologies. Use of this model is generally appropriate given its emphasis on perceived risks and benefits as core factors of GM/GE food acceptance (Scott et al., 2016; Marette et al., 2021a) and broad application and relevance for novel food technologies, and gene technologies in specific. In addition, it also brings together and encapsulates the aforementioned variables of interest identified in the literature, including factors that have been employed – thus providing a template, which we adapt and extend. These extensions involve some modifications in terms of the factors employed and, to a smaller extent, changes to the types of relationships that are hypothesized. By using this model, we moreover build upon the need for application of established models for evaluating food technologies, beyond common approaches, such as the TAM and UTAUT (Kamrath et al., 2023), along with the lack of modelling in consumer studies on gene-edited food acceptance (Strobbe et al., 2023).

In Siegrist's initial model, perceived risks and benefits are accompanied by three other factors: Worldview A (reflecting a positive view of the benefits of science and technology); Worldview B (tied to critiques of the former); and Social trust (in individuals responsible for development, regulation, and commercialization of the technology). While social trust was retained for this analysis, on account of evidence that the actor involved is impactful for acceptance (Lusk et al., 2018; Muringai et al., 2020; Marette et al., 2021a) and attention to this factor in the existing literature (Farid et al., 2020; Kato-Nitta et al., 2019; Kamrath et al., 2019), issues with the two "Worldview" measures identified in pre-testing (see Section 3.1) required that we replace them with a measure of environmental worldviews (New Ecological Paradigm (NEP) by Dunlap et al., 2000). This factor was deemed to be appropriate given its prior use for CRISPR (Shew et al., 2018; Ferrari et al., 2021) and its emphasis on critical aspects of technological innovation (similar to Worldview B in Siegrist, 1999, 2000). We included the food technology neophobia measure in Cox and Evans (2008) as well, given its relevance for behavioral intentions towards new food technologies (Vidigal et al., 2015; Kamrath et al., 2019; Siegrist and Hartmann, 2020; Baum et al., 2021; Ortega et al., 2022).

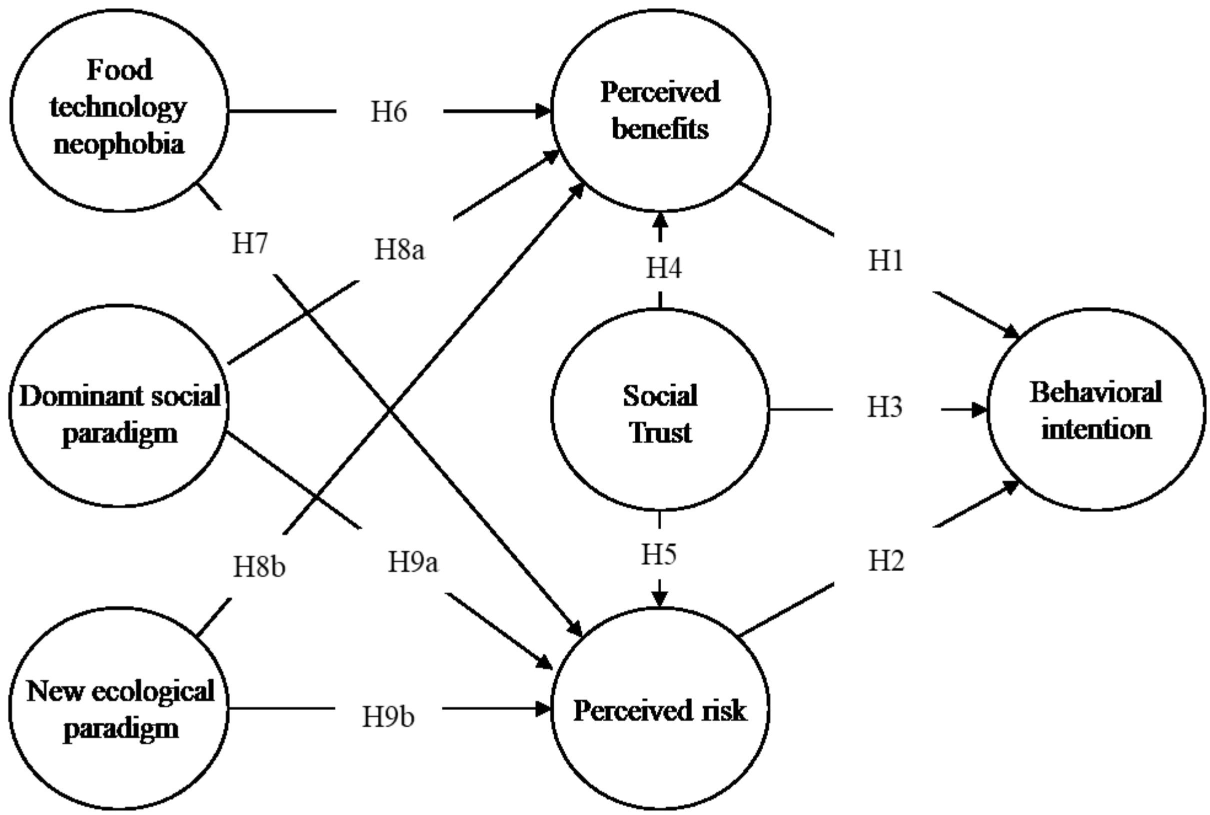

Figure 1. Hypothesized model for behavioral intentions towards CRISPR

Drawing on our literature review as well as the systematic analysis from Kamrath et al. (2019), we finally made two changes in terms of the underlying causal relationships of Siegrist's model. First, we excluded the indirect effect from perceived benefits to acceptance, through perceived risks. Both in the literature on CRISPR and more generally, we could not find reasons to assert this kind of primacy to perceived risks – indeed, our findings offer contrasting evidence in this regard, as we will show. Also, we proposed a potential direct effect of social trust on behavioral intentions, in order to offer a more comprehensive exploration of the role of this factor given its importance in the literature (Farid et al., 2020; Kato-Nitta et al., 2019; Muringai et al., 2020; Marette et al., 2021a). Accordingly, we explicitly examined the following hypotheses:

- *H1*: Increases in perceived benefits will have a positive effect on behavioral intentions.
- *H2*: Increases in perceived risks will have a negative effect on behavioral intentions.
- *H3*: Higher levels of social trust will have a positive effect on behavioral intentions.
- *H4*: Higher levels of social trust will have a positive effect on perceived benefits.
- *H5*: Higher levels of social trust will have a negative effect on perceived risks.
- *H6*: Greater fear of new food technologies will negatively impact perceived benefits.
- *H7*: Greater fear of new food technologies will positively impact perceived risks.

- *H8a*: Stronger endorsement of society exercising a dominant role over the environment will have a positive effect on perceived benefits.
- *H8b:* Stronger pro-environmental worldviews will have a negative effect on perceived benefits.
- *H9a*: Stronger endorsement of society exercising a dominant role over the environment will have a negative effect on perceived risks.
- *H9b:* Stronger pro-environmental worldviews will have a positive effect on perceived risks.

3 Methodology

3.1 Data collection

A standardized survey was conducted online in 2019 via Qualtrics in the United States, where just a few studies have empirically examined CRISPR acceptance (Shew et al., 2018; Busch et al., 2021; Marette et al., 2021a, 2021b) though applications are commercially available (Waltz, 2018). In case respondents were unfamiliar with CRISPR, the survey gave background details on the technique, possible applications to the food sector, and potential risks and benefits (See Supplementary Table A.1). Two comprehension questions were posed. If either was answered incorrectly, respondents were given a second chance to read the text and answer correctly. Only those answering correctly were able to continue. Two rounds of pilot testing were conducted, with changes made to the introductory text, addition of a second comprehension question, and the adoption of a measure for behavioral intention derived from Siegrist's acceptance measure (1999) and the inclusion of the environmental worldview measure in place of Worldview measures from Siegrist (1999) given difficulties with the initial ones. The decision to replace measures with those described below was specifically taken due to reliability and validity issues found by the preliminary analyses. Lastly, due to excessive use of the "No opinion" option in the 5-point Likert scale, we opted to use a 6-point scale without a null option and included two attention questions. Given concerns over careless reporting in online surveys (Ward and Meade 2023), we included two trap questions to assess attentiveness, which were inserted randomly into two of the survey blocks. Participants answering either of these incorrectly were removed from the sample. Also, in order to assess "inconsistent" patterns of responding, we screened for speeding through the survey, participants "straight lining" with the same answer throughout as well as repeatedly giving the same answer for reverse-coded pairs of items. Having identified these participants and having them replaced, the final sample consisted of 158 individuals.

3.2 Measures

This study employed six measures, all widely validated in the literature, with the exception of the behavioral intentions measure (Table A.2). We adapted the scales for social trust, perceived benefits, and perceived risks in Siegrist (1999), only making the necessary change from "gene technology" to the current application (see Supplementary Table A.3 for a full enumeration of factors). We integrated the food technology neophobia scale (FTNS) by Cox and Evans (2008) and New Ecological Paradigm (NEP) by Dunlap et al., (2000), as a measure of environmental worldviews. FTNS has proven useful to assess the level of anxiety or discomfort provoked by new food technologies (Vidigal et al., 2015; De Steur et al., 2016; Baum et al., 2021), including CRISPR food (Ortega et al., 2022). While this scale has been used to examine nanotechnology and biotechnology, it has not yet been used for CRISPR. Conversely, NEP has been used twice in the CRISPR literature (Shew et al., 2018; Ferrari et al., 2021) – but with inconsistent findings (Section 2.1). Of note, NEP aims to reflect the extent of the transition between two distinct worldviews: i.e., the dominant social paradigm (DSP), which encapsulated the status quo when first developed (Dunlap and van Liere; 1978) versus a more environmentally conscious view, described as the new environmental paradigm (NEnvP) (Anderson, 2012). Significantly, NEP is thereby composed of two sub-scales, each reflecting the level of agreement with a particular worldview – having identified the existence of two separate factors conforming to these scales, relevant hypotheses were proposed for each (i.e., *H8a, H8b, H9a, H9b*).

The dependent variable is defined as behavioral intention, measuring how much effort a person is planning to exert to perform the focal behavior (Ajzen 1991). Notably, this measure is used rather than acceptance, which focuses more on the degree of favor expressed by an individual towards an object, which itself informs the decision to adopt or reject (see Kamrath et al., 2023 for an overview of the approaches to measuring evaluation of novel food technologies). After surveying the literature on behavioral intention towards novel food technologies (e.g., Siegrist et al., 2007; Connor and Siegrist, 2010; Lusk et al., 2015; Maes et al., 2018; Kamrath et al., 2019), a seven-item measure was designed (Table A.3). The composite measure consisted of items that related to general interest or use (*BI1*, *BI2*), willingness to try or pay more for certain advantages or applications (*BI3, BI4, BI6*), and which consider the role of particular technological features (*BI5, BI7*). Pre-testing failed to identify any issues, for comprehension or in terms of reliability or validity. All measures used a 6-point scale without a neutral option (*1 – completely disagree* to *6 – completely agree*).

Finally, we included questions for socio-demographic factors of age, gender, and geographic region (checked at outset in line with quotas that were established), and education, income, and shopping frequency at the close of the survey. A description of these sample characteristics can be found in Table 1 (see Section 4.1). We inquired about shopping frequency to ensure that the respondents were at least somewhat engaged in household shopping and thus might be tasked with taking a decision on whether to purchase CRISPR products in the future.

3.3 Data analysis

Preliminary data analysis was performed using SPSS (version 25) to describe the characteristics of the sample based on the socio-demographic factors. To establish which (if any) determinants were relevant for behavioral intentions towards CRISPR, we employed partial least-squares structural-equation modeling (PLS-SEM) via SmartPLS 3.3. PLS-SEM offers a methodological approach for the estimation of complex causal relationships between factors, i.e., by combining confirmatory factor analysis (measurement model) and multiple regression analysis (structural model) (Hair et al., 2022). In addition, it is suitable since it does not require normally distributed data (Henseler et al., 2009). As a first step, validity and reliability of the overall measurement model were assessed using different indicators (outer loadings, average variance extracted, composite reliability, heterotrait-monotrait-ratio, Fornell-Larcker criterion). Once reliability and validity of the factors were confirmed, the hypothesized relationships within the model (see Figure 1) were tested by analyzing the structural model. For hypothesis testing, the bias-corrected and accelerated (BCa) bootstrapping procedure of 5000 subsamples and significance level of 0.05 on the basis of a two tailed test was applied (as recommended by Hair et al., 2022).

4 Results

4.1 Description of sample

The survey was conducted online via Qualtrics, with a sample of 158 individuals in the US. The sample was stipulated to have an even gender split, include those over 18, and have equal geographic distribution across the Northeast, South, Midwest, and West. As a result, the sample is representative in terms of gender and age, and has distributed regional representation, though this resulted in the South being underrepresented (-13.2%) relative to the general population (Table 1). Regarding education, those with a high-school degree or its equivalent and those who did not complete high school were both under-represented; those having completed a few years of college accounted for most of this difference. Conversely, the sample is well-distributed in terms of household income, with only the highest level under-represented (-13.8%). Responses to shopping frequency also confirmed that all respondents were at least somewhat responsible for shopping. Since significant influences of the socio-demographics for behavioral intentions towards CRISPR could not be identified, we do not include them in the further analysis.

Table 1. Sociodemographic characteristics for the sample

Characteristic	Category	N (%)	Census 2019 in %	Difference (Sample-Census)
Age	18-24	20 (12.7%)	13.0%	-0.3%
	25-34	23 (14.6%)	17.1%	-2.5%
	35-44	30 (19.0%)	17.1%	1.9
	45-54	31 (19.6%)	19.2%	0.4
	Over 55	54 (34.2%)	32.8%	1.4
Gender[a]	Female	80 (50.6%)	51.0%	-0.4%
	Male	77 (48.7%)	49.0%	-0.3%
Education[b]	Did not complete high school	9 (5.7%)	10.6%	-4.9%
	High-school degree or equal	26 (16.5%)	28.3%	-11.8%
	Some college	41 (25.9%)	18%	7.9%
	Associate degree	19 (12.0%)	9.8%	2.2%
	Bachelor's degree	40 (25.3%)	21.3%	4%
	Graduate degree	22 (13.9%)	12.0%	1.9%
Household income (before taxes)	< $20,000	25 (15.8%)	13.1%	2.7%
	$20,000 to $34,999	23 (14.6%)	12.3%	2.3%
	$35,000 to $49,999	27 (17.1%)	11.7%	5.4%
	$50,000 to $74,999	30 (19.0%)	16.5%	2.5%
	$75,000 to $99,999	21 (13.3%)	12.3%	1.0%
	> $100,000	32 (20.3%)	34.1%	-13.8%
Geographic region	Northeast	40 (25.3%)	17.2%	8.1%
	Midwest	40 (25.3%)	21.6%	3.7%
	South	40 (25.3%)	38.5%	-13.2%
	West	38 (24.1%)	22.7%	1.4%
Shopping frequency	More than once a week	77 (48.7%)		
	Weekly	63 (39.9%)		
	Less than once a week	18 (11.4%)		

Note: [a]one participant preferred not to say; [b]one missing value.

4.2 Measurement model results

The respective values for item loadings, convergent validity (*AVE*), composite reliability (*CR*), of all reflective constructs are shown in Table 2. Most of the standardized item loadings of the six constructs exceeded the limit of 0.708 (see Hair et al., 2022), while still more exceeded the acceptable threshold of 0.45 for a sample size of more than 150 (Hair et al., 2022). Nonetheless, others (*FTNS13*, *PR4*) needed to be deleted from the overall model due to insufficient loadings. Especially for the NEP scale, 11 out of 15 items would have needed to be excluded; though on further inspection this pointed to the existence of distinct sub-scales: dominant social paradigm (*DSP*) and new environmental paradigm (*NEnvP*) (Anderson 2012). Accordingly, we separated the sub-scales and established two distinct factors, which resulted in the exclusion of 5 of the 15 items (*DSP3*, *DSP5*, *DSP6*, *NEnvP1*, *NEnvP6*). Moreover, given that the sub-scales can be expected to differentially relate to the other factors, i.e., perceived risks and perceived benefits, we proposed hypotheses in line with the literature (e.g., Anderson, 2012): *H8a*: *DSP* → *PB* (+), *H9a*: *DSP* → *PR* (-), *H8b*: *NEnvP* → *PB* (-), *H9b*: *NEnvP* → *PR* (+). Next, to ensure convergent validity, four items (*FTNS6*, *FTNS7*, *FTNS10*, *PR7*) were deleted so that all six indicators had values of average variance extracted (*AVE*) above the threshold of 0.5 (Hair et al., 2022). In terms of composite reliability, the indicators met the threshold of 0.7 that ensures a satisfactory level of internal consistency of constructs within the proposed model (Hair et al., 2019).

Table 2. Results for the measurement model from PLS-SEM analysis.

Constructs[a]	Factor loadings[b]	AVE [c]	C.R.[d]	Constructs[a]	Factor loadings[b]	AVE [c]	C.R.[d]
PR		0.515	0.841	**FTNS**		0.515	0.905
PR1	0.732			FTNS1	0.787		
PR2	0.720			FTNS2	0.640		
PR3	0.674			FTNS3	0.787		
PR5	0.757			FTNS4	0.706		
PR6	0.703			FTNS5	0.726		
PB		0.735	0.917	FTNS7	0.602		
PB2	0.771			FTNS8	0.717		
PB3	0.847			FTNS11	0.772		
PB4	0.905			FTNS12	0.697		
PB5	0.900			**DSP**		0.511	0.800
BI		0.700	0.942	DSP1	0.674		
BI1	0.831			DSP2	0.840		
BI2	0.882			DSP4	0.464		
BI3	0.869			DSP7	0.817		
BI4	0.870			**NEnvP**		0.527	0.868
BI5	0.868			NEnvP2	0.796		
BI6	0.742			NEnvP3	0.806		
BI7	0.782			NEnvP4	0.580		
Trust		0.545	0.825	NEnvP5	0.671		
TRU1	0.821			NEnvP7	0.765		
TRU2	0.590			NEnvP8	0.711		
TRU3	0.790						
TRU4	0.729						

Note: [a] BI = behavioral intention, DSP = dominant social paradigm, FTNS = food technology neophobia scale, NEnvP = New Environmental Paradigm, PB = perceived benefits, PR = perceived risks; TRUST = social trust. [b] all outer loadings are significant at a level of 0.000; [c] AVE = average variance extracted; [d] C.R. = construct reliability. Detailed list of items is provided in Table A.3.

Looking at inner and outer Variance Inflation Factor (*VIF*), no construct items indicated issues with multicollinearity, as VIF values were below 5 (Hair et al., 2022). Also, all inner VIF values were below 3.3, signaling the absence of common method bias (Kock, 2017). As a further check here, the issue of common method bias was assessed using the test of full collinearity proposed by Kock and Lynn (2012). To also examine if there might be collinearity between the dependent variable and one (or more) predictor variables, this test regresses all variables against a common variable. If the VIF≤3.3, then it can be concluded that common method bias is not an issue. As the analysis (Table 3) yielded no factor with a value above 3.3, we conclude common method bias is not a serious issue with the data. **Table 3**. Full collinearity testing

BI	*DSP*	*FTNS*	*NEnvP*	*PB*	*PR*	*TRUST*
3.040	1.402	1.916	1.215	3.065	1.049	1.406

Assessment of discriminant validity examined the heterotrait-monotrait-ratio (HTMT) indices, shown in Table 4. HTMT values less than 0.85 indicate if a construct is distinct from the other latent constructs (Hair et al., 2022). This was true for all pairs except *PB*/*FTNS* and *PB*/*BI*. After deleting *PB1*, the HTMT value of *PB*/*FTNS* also met the threshold. In any case, we note that Henseler et al. (2015) have suggested a threshold of 0.90 if the path model includes constructs that are conceptually very similar, which *PB* and *BI* are. For further confirmation, we employed the Fornell-Larcker criterion (Fornell and Larcker 1981).[1] Since the squared root of the AVE for behavioral intentions is greater than the correlation of behavioral intentions and perceived benefits ($\sqrt{AVE_{BI}} = 0.836 \geq 0.811 = corr_{BI/PB}$), this offers further support of discriminant validity between *PB* and *BI*. In sum, there is sufficient evidence of composite reliability, convergent validity, and discriminant validity.

Table 4. Discriminant validity of the revised model – Heterotrait-Monotrait Ratio (HTMT).

Constructs[a]	1	2	3	4	5	6
1. BI						
2. DSP	0.572					
3. FTNS	0.773	0.425				
4. NEnvP	0.139	0.332	0.192			
5. PB	0.893	0.616	0.804	0.116		
6. PR	0.501	0.262	0.601	0.404	0.500	
7. TRUST	0.683	0.560	0.663	0.303	0.811	0.741

Note: [a] BI = behavioral intention, DSP = dominant social paradigm, FTNS = food technology neophobia scale, NEnvP = new environmental paradigm, PB = perceived benefits, PR = perceived risks; TRUST = social trust.

4.3 Structural model results

The standardized regression coefficients, their significance levels, and effect sizes are presented in Table 5. The hypothesized relationship *PB* → *BI* (H_1, β = 0.754, t = 12.364, f^2 = 0.960) was found to be positively significant with large effect size, while the negative relationship between *PR* → *BI* (H_2, β = -1.01, t = 1.743, f^2 = 0.021) was not significant. The existence of a significant

[1] There has been some criticism of the robustness of the Fornell-Larcker criterion for establishing discriminant validity in the context of PLS-SEM research. For instance, Henseler et al. (2015) indicate the Fornell-Larcker criterion did not always perform well, especially when indicator loadings were rather similar (i.e., loadings are between 0.65 and 0.85), while Radomir and Moisescu (2020) and Franke and Sarstedt (2019) similarly conclude that the Fornell-Larcker criterion often fails to detect a lack of discriminant validity in the context of PLS-SEM. Given that HTMT and the Fornell-Larcker criterion offer support for discriminant validity, there is no issue.

relationship *TRUST* → *BI* could not be supported by our data set (H_3, β = 0.022, t = 0.279, f^2 = 0.001). The relationship *TRUST* → *PB* (H_4, β = 0.303, t = 4.261, f^2 = 0.189) was however found to be positively significant, and *TRUST* → *PR* (H_5, β = -0.373, t = 4.474, f^2 = 0.152) negatively and significant, both with medium effect sizes. As proposed, the relationship *FTNS* → *PB* (H_6, β = -0.472, t = 6.975, f^2 = 0.508) was negatively significant with large effect size, while *FTNS* → *PR* (H_7, β = 0.295, t = 3.321, f^2 = 0.016) was positively significant with small effect size.

Table 5. Path coefficients after bootstrapping.

Hypotheses[a]	Path[b]	Path coefficient (f^2)[c]	Conclusion (Hypotheses)
	Direct effects		
H_1	PB → BI	0.754*** (0.960)	*NR*
H_2	PR → BI	-0.101 (0.021)	*R*
H_3	TRUST → BI	0.022 (0.001)	*R*
H_4	TRUST → PB	0.303*** (0.189)	*NR*
H_5	TRUST → PR	-0.373*** (0.152)	*NR*
H_6	FTNS → PB	-0.472*** (0.508)	*NR*
H_7	FTNS → PR	0.295*** (0.016)	*NR*
H_{8a}	DSP → PB	0.293*** (0.232) [a]	*NR*
H_{9a}	DSP → PR	0.104 (0.016) [a]	*R*
H_{8b}	NEnvP →PB	0.125*** (0.049) [b]	*OPP*
H_{9b}	NEnvP → PR	0.283*** (0.135) [b]	*NR*
	Specific indirect effects		
	TRUST → PB → BI	0.228***	
	TRUST → PR → BI	0.038	
	FTNS → PB → BI	-0.356***	
	FTNS → PR → BI	-0.030	
	DSP → PB → BI	0.221***	
	DSP → PR → BI	0.011	
	NEnvP → PB → BI	0.094**	
	NEnvP → PR → BI	-0.029	

Note: [a] NR = hypothesis cannot be rejected, R = hypothesis is rejected, OPP = relationship is significant but in the opposite direction to that hypothesized; [b] BI = behavioral intention, DSP = dominant social paradigm, FTNS = food technology neophobia scale, NEnvP = new environmental paradigm, PB = perceived benefits, PR = perceived risks; TRUST = social trust; [c] *** significance level 0.000, **significance level of 0.05.

The relationship *DSP* → *PB* (H_{8a}, β= 0.293, t = 4.153, f^2 = 0.232) was negatively significant with medium effect size, while *DSP* → *PR* (H_{9a}) was not significant. For the *NEnvP* construct, both *NEnvP* → *PB* (H_{8b}, β = 0.125, t = 2.353, f^2 = 0.049) and *NEnvP* → *PR* (H_{9b}, β = 0.283, t= 3.791, f^2 = 0.135) were positively significant with small effect sizes. As such, the relationship between *NEnvP* → *PB* was not in line with H_{8b}, though *DSP* → *PB* did conform to H_{8a}. The relationship between *NEnvP* → *PR* was positively significant and in line with H_{9b}, though small in effect size; *DSP* → *PR* however was not found to be significant (H_{9a}).

All of the indirect effects that involve perceived benefits are found to be significant, and with the same sign as the direct effect. These findings highlight the prominence of perceived benefits for explaining behavioral intentions towards CRISPR, and, specifically, that the indirect effects bolster the strength and direction of the direct effect. In contrast, none of the indirect effects that involve perceived risks turned out to be significant.

Lastly, the percentages of extracted variance (R^2) were 66.7%, 71.0%, and 45.5%, respectively, for *BI*, *PB*, and *PR*. Applying the blindfolding procedure, we calculate Stone-Geisser's Q^2 value for reflective items, which indicates the model's predictive relevance for values larger than zero (Hair et al., 2022). In this study, we found that the structural model met the recommended limit of zero, implying good predictive relevance (Q^2_{BI} = 0.454, Q^2_{PB} = 0.504, Q^2_{PR} = 0.219).

5 Discussion

Given the controversial legacy of GM food, the ever-present question of public acceptance of novel food technologies is always close at hand. Indeed, whenever a nation decides to 'opt out' of giving approval to biotechnology, there is recurring mention of the discomfort and anxiety that preceded these actions (e.g., Gaskell et al., 2004, 2011; Hess et al., 2016; Scott et al., 2018; Malyska et al., 2016), with lingering questions of the extent to which such concerns might carry over to next-generation GE techniques (Hartley et al., 2016; Bartkowski et al., 2018; Agapito-Tenfen et al., 2018; Eriksson et al., 2018; Bain et al., 2020; Siebert et al., 2021).

The principal takeaway from this research is the importance of perceived benefits for behavioral intentions towards CRISPR, especially in relation to perceived risks. Perceived benefits are here found to have a significantly positive influence on behavioral intentions, and with a large effect size. In line with other studies in the literature (Shew et al., 2018; Ferrari et al., 2021; Yang and Hobbs, 2020; Busch et al., 2021; Marette et al., 2021a, 2021b), this result strongly illustrates the role of benefit perceptions on increasing consumer willingness to try and consume CRISPR food. Unlike Farid et al. (2020) and Yang and Hobbs (2020), we find no clear evidence that risk perceptions have any impact on behavioral intentions towards CRISPR. This is notable given that, first, it underscores that promoting acceptance of CRISPR demands that individuals first and foremost be "shown the benefits" of these technologies. And second, this finding points to a potential difference between GM and CRISPR food, in view of how much the story of the former, principally in the media but also the scientific literature, has featured the importance of dispelling or "correcting" individual perceptions of risks (Frewer et al., 2003, 2011; Gaskell et al., 2011; Scott et al., 2018; Siegrist and Hartmann, 2020). However, as Siegrist and Hartmann (2020) postulated, the apparent prominence of risks is linked with concerns around the lack of safety or unnaturalness of novel food technologies, plus the relative ease with which terms such as “Frankenfood” are available as heuristics for decision-making. In contrast, the awareness and understanding of the potential benefits of such technologies are not immediately intuitive in many cases.

While, at first glance, this would appear to hamstring efforts to promote a richer discussion of how CRISPR, *inter alia*, can assist societies in tackling the challenges they presently face, it is clear from our study that attempts to engage with the public should lead with the benefits, rather than being overly concerned with how the public (mis)perceives the prospective risks. In this vein, Kato-Nitta et al. (2019) have provided a potential option, by identifying how information provision (i.e., promoting literacy of basic science) proved effective in shifting attitudes towards GE/GM food only for benefit perceptions, and not for value or risk perceptions. In other words, it could be that the prospects of engaging with the public are strongest for the benefits of this novel technology, which according to our results (in the context of the United States) is exactly where the strongest linkages to behavioral intentions are. Indeed, the strength of the relationship between perceived benefits and behavioral intentions provides either a significant counterpoint to the argument that benefits are not so relevant for acceptance (e.g., Scott et al., 2018; Siegrist and Hartmann, 2020) or marks a principal point of distinction between GM and GE food.

Furthermore, the use of a structural model for this analysis enables us to examine the interplay among the various factors, in addition to their direct effects on behavioral intentions, as well as to distinguish the direct from the indirect effects of factors such as social trust, food technology neophobia, and environmental worldviews. In light of the above, this latter finding is especially useful in order to understand additional ways in which individual perceptions of benefits might be influenced. Given a lack of structural models in the CRISPR literature and, more generally, a limited attention to perceptions of benefits (or risks) as the focus of analysis, the established findings of this kind are that knowledge has a positive impact on perceived benefits, along with perceived risks interestingly (Farid et al., 2020), and that experts have higher perceptions of the benefits of CRISPR vis-à-vis the lay public (Kato-Nitta et al., 2019). Here, the current results make clear that social trust in those involved in the research, development, and regulation of CRISPR also has a positive direct effect on perceived benefits in the United States – as well as a negative effect on perceived risks. Accordingly, this reinforces the broad importance of social trust in informing lay perceptions of risks and (especially) benefits of gene technologies (Prati et al., 2012; Siegrist, 2000; Zhang et al., 2018). Having accounted for indirect effects of social trust via perceived benefits (and risks), moreover, we failed to replicate the finding by Farid et al. (2020) that trust directly influences behavioral intentions; rather, all of its effect occurs indirectly through perceived benefits and risks. More consideration should be given to the role of social trust for perceptions and acceptance of CRISPR in future research.

Additionally, our structural model weighed the importance of two other factors that have so far received limited attention in relation to CRISPR: food technology neophobia and environmental worldviews. In specific, food technology neophobia has a negatively significant influence on perceived benefits, whereby those more fearful of novel food technologies had a dimmer view of the benefits of CRISPR. In fact, this factor has the second-largest effect size in the overall model, only behind that of perceived benefits on behavioral intentions. Further, food technology neophobia has an opposite effect on perceived risks, though the effect size is small. The impact of food technology neophobia on both risks and benefits reveals its importance to understanding acceptance of CRISPR, as established for other novel food technologies (Kamrath et al., 2019; Siegrist and Hartmann, 2020; Baum et al., 2021) and CRISPR food in particular (Ortega et al., 2022). Of course, other studies (Rousseliére and Rousseliére, 2017; Farid et al., 2020; Muringai et al., 2020; Yang and Hobbs, 2020; Marette et al., 2021a) highlighted the relevance of general attitudes towards food innovations and technologies, specifically, those with positive attitudes tend to be more favorable towards CRISPR food. At the same time, the tendency for how this factor is conceived to vary across studies is suggestive of a need for a more cohesive approach, e.g., to facilitate the comparisons of results and in pursuit of generalizability (see Kamrath et al., 2019). As such, together with Ortega et al. (2022), the current study is hopefully the first of many to use the widely validated scale of food technology neophobia to better understand social acceptance of CRISPR food.

In similar fashion, the structural model revealed the significance of environmental worldviews vis-à-vis the sub-scales of Dominant Social Paradigm (DSP) and New Environmental Paradigm (NEnvP) of the New Ecological Paradigm (NEP) (Dunlap et al., 2000). Counter to expectations, these items failed to load onto a single factor but rather needed to be included separately (see Section 3.2). By doing so, we however ascertain, first, that those with more pro-environmental worldviews (i.e., higher values for NEnvP) perceived CRISPR as having higher levels of risks and benefits, both effects of small size. Second, given the positively significant, medium-sized effect of DSP on perceived benefits, those of a more techno-centric perspective on humanity's relationship with the environment took a more positive view on benefits of CRISPR. Together, these findings highlight the joint influences of two types of environmental worldviews, with those seeking to protect the environment and those viewing it to be at the disposal of the needs of mankind each more receptive to the benefits of CRISPR – and, indirectly through such perceptions, with stronger behavioral intentions towards CRISPR. In addition, those wishing to protect the environment were more likely to perceive CRISPR to have risks worth considering – indeed, this effect size was about three times larger than that for benefits, though it would still be characterized as small. The influence of a pro-environmental worldview (represented by NEvnP) thus tends to be two-sided, while a more techno-centric worldview (represented by DSP) only influenced benefit perceptions. Our use of NEP, specifically its composite sub-scales, thus reinforces the findings of Rousseliére and Rousseliére (2017), while simultaneously adding more nuance. Individuals with interest in the environment are not only more skeptical of GE food but also, in some respects, optimistic; this finding advises caution, as a result, about making broad distinctions between, e.g., those with positive views over science and technology versus those with positive views on the environment (see also Ferrari et al., 2021). In this regard, our findings are closer to Shew et al., (2018), who established beliefs in the "environmental helpfulness" of CRISPR as a key driver of willingness to consume – even if they did not find a particular effect of NEP. It is not possible to say, given differences in study design, but the divergence over the role of NEP could stem from whether the two sub-scales are distinguished from one another. Especially in view of frequent references to potential environmental benefits of CRISPR, more attention should be paid to the impact of environmental worldviews.

At the same time, it is important to keep in mind some limitations of the present study. On NEP, for instance, some of the issues accompanying this factor, notably, regarding the loading of certain items and the contrary-to-expectations effect of NEnvP on perceived benefits, are reflective of difficulties experienced by other studies (e.g., Cruz and Manata, 2020; Lalond and Jackson, 2002). In specific, we note that studies have raised the question of whether the scale may have anywhere from one to five dimensions (Amburgey and Thoman, 2012; Rosa et al., 2021), and more generally potential alternate measures have also been suggested (e.g., Stern, 2000; Steg and Vlek, 1999). As such, the generalizability of our results, although significant, should be approached with caution – e.g., it may be that NEnvP is positively related to perceived benefits and perceived risks because this factor is comprised of more than one sub-dimension, even if this was not borne out by principal components analysis. Hence, we hope the results will prove the subject of future replication efforts, either towards repeated demonstration of the NEP or the use of alternative measures. Secondly, we highlight the potential overlap among the measures for perceived benefits and behavioral intentions, given that the HTMT value here was 0.893. Notably, this value falls between the thresholds set by Hair et al. (2022), i.e., 0.85, and Henseler et al. (2015), i.e., 0.90. As outlined in Section 4.2, we opted for the latter since our path model included constructs that were conceptually similar in nature, which is one of the provisions for doing so. Also, looking at the measures themselves (Table A.3), the constituent items for these two differ, *inter alia*, in their reference to and emphasis on (intentional) activities like consuming, trying, and paying more. Insofar as there is overlap between the two, one possibility might be that this results from careless reporting, such that the correlation between these two factors has become inflated (Ward and Meade 2023). At the same time, while careless reporting is always something to consider for online surveys, both the relatively short length of the survey and the multiple steps taken to identify, screen out, and remove careless respondents (see Section 3.1) make this less a reason for concern. Alternately, the high correlations might be reflective of a more hypothetical bias which affects investigation of CRISPR-edited attitudes and preferences at the present. In this respect, it could speak to the novelty of this food technology and, as a result, the fact that knowledge and intentions might not yet be so established. And yet, given the similarity in both the design and orientation of the measures for perceived benefits and risks, if the foregoing would explain why the perceptions of benefits would overlap with behavioral intentions, we would expect the same to hold true for perceived risks. This is however not the case. Also of interest, even though social trust is significantly related to perceived benefits (and perceived risks), this is not true for behavioral intentions. As such, while perceived benefits and behavioral intentions are strongly related, they are not identical in their relationships to other variables of interest. More than anything, the results of our structural model underscore the relevance of perceived benefits for understanding the potential acceptability of CRISPR-edited food, along with highlighting the need for deeper consideration of this factor in future research.

In sum, the present research offers relevant insights on behavioral intentions towards CRISPR, and specifically highlights the prominence of perceived benefits. Through the use of a structural model, we illuminated the interplay between individual perceptions of benefits and risks on the one hand, and social trust, food technology neophobia, and environmental worldviews on the other. In this way, we have strived to demonstrate the value of structural models for examining consumer acceptance of CRISPR food, with the hope of more such models appearing in future research – along with the more frequent use of widely validated scales in order to render results more readily comparable across studies. In this vein, we also acknowledge the need to evaluate the generalizability of these findings, beyond the United States, by testing this model in other contexts and potentially through cross-country studies. Indeed, cross-country disparities in the perceptions and acceptance of CRISPR food have been indicated by a few studies so far (Shew et al., 2018; Busch et al., 2021; Marette et al., 2021a, 2021b). It will be interesting and important to continue to track the emergence and evolution of such differences across countries as more food-related applications of CRISPR come to market – or are prevented from doing so.

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Appendix

Table A.1. Introductory text and comprehension questions (correct answer underlined).

Condition	Message
Introductory information	Just like people have traits – blue eyes, brown hair, tall vs. short – plants and animals have traits too, like disease and frost resistance, smaller seeds, large vs. small leaves, all influenced by DNA. In the past few years, a new technology has been developed that enables scientists to make changes to DNA inside living things – plants, animals, humans – cheaper, easier and faster than ever before. The technology is called CRISPR (pronounced "crisper") and like a pair of molecular scissors, CRISPR is programmed to locate a specific DNA sequence and make cuts that then allow for a trait to be turned off or a new trait to be added. CRISPR changes the DNA code by swapping out individual parts or groups of new DNA code after the DNA sequence has been cut. For instance, scientists in 2016 utilized CRISPR to create an anti-browning mushroom by targeting a DNA sequence that control how mushrooms react to oxygen. Whereas the CRISPR-edited mushroom was created by removing DNA, and thereby turning off a specific trait, scientists have also utilized CRISPR to insert new DNA into a wide variety of staple crops (corn, rice and wheat) and thereby attain novel traits such as drought resistance. CRISPR has also been used to make strawberries that are more nutritious and strains of wheat that are low in gluten. In spite of the many benefits and potential applications, CRISPR is not without its risks, such as unwanted or "off-target" changes across the total DNA or increased cancer risk caused by editing. The potential for such issues, as well as a high-profile experimental trial involving the gene-editing of human embryos, have caused scientists to question how and when the tool should be used and whether its use ought to be broadly regulated.
Question #1	CRISPR is a tool for editing DNA. • <u>True</u> • False
Question #2	Which of the following is a way that CRISPR can be used to modify (plant or animal) DNA? • Switch a trait on or off • Include a trait that was not previously obtainable/available • <u>Both are possible</u> • None of the above

Table A.2. Overview of measures.

Measure	Description
New ecological paradigm	8-item measure (sub-scale of New environmental paradigm, from Dunlap et al. 2000)
Dominant social paradigm	7-item measure (sub-scale of New environmental paradigm, from Dunlap et al. 2000)
Food technology neophobia	13-item measure (from Cox and Evans 2008)
Social trust	4-item measure (adapted from Siegrist 1999)
Perceived benefits	6-item measure (adapted from Siegrist 1999)
Perceived risks	7-item measure (adapted from Siegrist 1999)
Behavioral intention	7-item measure (based on e.g. Siegrist et al. 2007; Connor and Siegrist 2010; Lusk et al. 2015; Maes et al. 2018; Kamrath et al. 2019)
Demographics	1-item measures for: age, gender, geographic region, education, income, and shopping frequency

Table A.3. Mean and standard deviation of items for all factors – Original model.

Factor (F)/Item (I)[a]	Sample Mean	Standard Deviation
F1 Perceived Risks		
PR1 The products of CRISPR could become dangerous to mankind.	0.670	0.075
PR2 When CRISPR technology combines genetic material of plants and animal species, irreversible damage to the environment becomes possible.	0.653	0.070
PR3 There is a great danger that by using CRISPR technology biological weapons will be produced.	0.584	0.086
PR4 CRISPR technology is a technology like many others. The risks should not be overdramatized.	0.407	0.127
PR5 The release of CRISPR-edited organisms into the environment is connected with great unknown risks.	0.694	0.058
PR6 There are still unknown risks related to using CRISPR technology.	0.683	0.051
PR7 There are little to no risks as long as scientists using CRISPR alter only the current generation's DNA, making sure no changes are passed on to future generations.	0.572	0.082
F2 Perceived Benefits		
PB1 CRISPR only increases the profit made by industry and is not beneficial to mankind at all.	0.466	0.118
PB2 It is irresponsible not to utilize CRISPR technology in producing new medications, if by its use human suffering can be eased.	0.752	0.069
PB3 Thanks to CRISPR technology, food and energy for the world's growing population can be produced in a more environmentally friendly way.	0.829	0.055
PB4 Thanks to CRISPR, the quality of life of mankind is increased.	0.897	0.021
PB5 If we take all aspects into account, we can say that our society profits from CRISPR technology.	0.906	0.017
F3 Behavioral Intention		
BI1 I see no problem with consuming medicine produced using CRISPR.	0.832	0.032
BI2 I would be interested in buying CRISPR-edited food.	0.881	0.019
BI3 I am willing to try CRISPR-edited food if less chemicals were used to produce them.	0.869	0.024
BI4 If a food produced using CRISPR was healthier than the alternatives, I would consider purchasing it.	0.872	0.028
BI5 CRISPR should be used to maximize the potential of plants and animals, whether by removing or adding genetic material.	0.869	0.025
BI6 I would pay more for CRISPR-edited food if it meant reducing my ecological footprint.	0.742	0.042
BI7 I am comfortable with CRISPR being used to cut out unwanted sections of DNA, but not adding new DNA.	0.781	0.032
F4 Trust		
TRU1 I trust that the CRISPR technology can be adequately controlled through appropriate regulations.	0.821	0.026
TRU2 Corporations involved with CRISPR are aware of their responsibilities.	0.597	0.092
TRU3 The authorities cannot sufficiently monitor whether scientists using CRISPR technology abide by legal regulations and restrictions.	0.781	0.050
TRU4 Scientists using CRISPR are hardly able to estimate or predict the	0.728	0.055

	consequences of their work.		
F5 Food Technology Neophobia			
FTNS1	There are a plenty of tasty foods around so we don't need to use food technology to produce more.	0.739	0.048
FTNS2	The benefits of new technologies are often grossly overstated.	0.606	0.095
FTNS3	New food technologies decrease the natural quality of food.	0.769	0.037
FTNS4	There is no sense trying out high-tech food products because the ones I eat are already good enough.	0.653	0.065
FTNS5	New foods are not healthier than traditional foods.	0.683	0.052
FTNS6	New food technologies are something I am uncertain about.	0.521	0.109
FTNS7	Society should not depend heavily on technologies to solve its food problems.	0.571	0.074
FTNS8	New food technologies may have long term negative environmental effects.	0.735	0.050
FTNS9	It can be risky to switch to new technologies too quickly.	0.564	0.065
FTNS10	New food technologies are unlikely to have long term negative health effects.	0.503	0.091
FTNS11	New products produced using new food technologies can help people have a balanced diet.	0.765	0.044
FTNS12	New food technologies give people more control over their food choice.	0.667	0.059
FTNS13	The media usually provides a balanced and unbiased view of new food technologies.	0.321	0.104
F6 New Ecological Paradigm[b]			
NEnvP1	We are approaching the limit of the number of people the Earth can support.	0.026	0.313
DSP1	Humans have the right to modify the natural environment to suit their needs.	0.567	0.220
NEnvP2	When humans interfere with nature it often produces disastrous consequences.	0.382	0.245
DSP2	Human ingenuity will insure that we do not make the Earth unlivable.	0.590	0.270
NEnvP3	Humans are seriously abusing the environment.	0.325	0.288
DSP3	The Earth has plenty of natural resources if we just learn how to develop them.	-0.051	0.202
NEnvP4	Plants and animals have as much right as humans to exist.	0.234	0.248
DSP4	The balance of nature is strong enough to cope with the impacts of modern industrial nations.	0.363	0.219
NEnvP5	Despite our special abilities, humans are still subject to the laws of nature.	0.428	0.173
DSP5	The so-called “ecological crisis” facing humankind has been greatly exaggerated.	0.361	0.242
NEnvP6	The Earth is like a spaceship with very limited room and resources.	0.133	0.287
DSP6	Humans were meant to rule over the rest of nature.	0.281	0.207
NEnvP7	The balance of nature is very delicate and easily upset.	0.336	0.285
DSP7	Humans will eventually learn enough about how nature works to be able to control it.	0.608	0.254
NEnvP8	If things continue on their present course, we will soon experience a major ecological catastrophe.	0.256	0.328

[a] Order of the factors does not reflect flow of the survey. Within the survey, order was as follows: FTNS, NEP, PR, TRUST, PB, BI. [b]The eight odd-numbered items pertain to the NEnvP sub-scale, and the seven even-numbered items to the DSP sub-scale.