The National Bioengineered Food Disclosure Standard of 2016: Intersection of Technology and Public Understanding of Science in the United States

Brianne Suldovsky
Portland State University, brianne.suldovsky@pdx.edu

William K. Hallman
Rutgers University - New Brunswick/Piscataway

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Brianne Suldovsky [1],* and William K. Hallman [2]

1 Department of Communication, Portland State University, Portland, OR 97201, USA
2 Department of Human Ecology, Rutgers University, New Brunswick, NJ 08901, USA
* Correspondence: brisul33@pdx.edu

Abstract: Genetically modified (GM) foods have been commercially available in the US for more than two decades, yet Americans know very little about them. With the implementation of the National Bioengineered Food Disclosure Standard of 2016, food manufacturers will be required to disclose the presence of GM ingredients in their food products. How food manufacturers communicate with consumers about GM ingredients may have consequences for public understanding of GM technology. In Study 1, we explore how food manufacturers characterize GM ingredients within their food products on SmartLabel, a digital disclosure website established by the Grocery Manufacturers Association. In Study 2, we test the effect of those characterizations on perceived risks and benefits of GM food. Overall, we find that varying characterizations of GM ingredients do not significantly affect perceived risks and benefits. Post hoc analyses suggest that knowledge of GM technology and moral evaluation of GM technology significantly predict perceived risks and benefits. Implications for the public communication of GM technology are discussed.

Keywords: biotechnology; genetically modified food; GM disclosure; National Bioengineered Food Disclosure Standard

1. Introduction

The US is the largest producer of genetically modified (GM) agricultural products in the world, with more than 75 million hectares (185 million acres) planted in GM crop varieties, amounting to nearly 40% of the global harvest of GM crops [1]. Current data from the US Department of Agriculture show that 92% of the corn, 94% of the soy, 94% of the canola, and 95% of the sugar beets grown in the United States are genetically modified (GM) [2]. Because these GM crops are used to make oils, flours, starches, thickeners, sweeteners, and other key ingredients used in the food industry, the Grocery Manufacturer's Association has suggested that seventy to eighty percent of the foods consumed in the United States contains ingredients derived from a GM plant [3].

GM foods have been available for purchase in the US for more than two decades, beginning with the introduction of the Flavr Savr tomato in 1994 [4]. The rapid uptake of GM crops by farmers since then makes GM crops the fastest adopted crop technology in modern agricultural history [5]. By the year 2000, more than half of the soybeans planted in the US were GM varieties, and by 2005, more than half of the corn planted in the US were GM [6]. As a result, as early as 2001, the Genetically Engineered Organisms Public Issues Education (GEO-PIE) project at Cornell University reported that, "recent estimates suggest that 60 to 70% of foods in US markets contain at least a small quantity of some crop that has been genetically engineered" [7]. GM crops also demonstrate a host of benefits at a variety of scales including, but not limited to, higher crop yields, fewer environmental inputs, and reduced production costs [8].

Despite their extensive presence within the US food supply and documented benefits, surveys of public awareness of GM foods have consistently shown that Americans know very little about them. For example, Hallman, Cuite, and Morin [9] found that more than half of Americans (54%) report knowing very little or nothing at all about genetically modified foods, and about one quarter of consumers say they have never heard of GMOs. In addition, studies show that fewer than half of Americans (43%) are aware that such products are currently for sale in supermarkets and that the majority of these consumers are confused about which GM food products are for sale [10]. For example, more than half of those who believe that GM foods are available in US supermarkets mistakenly believe that GM tomatoes, wheat, and chicken are for sale, while fewer than half are aware that GM soy products are available. The Hallman, Cuite, and Morin study also found that only about one-quarter of Americans (26%) believe that they have ever eaten any food containing GM ingredients. Consistent with these findings, data from the Pew Research Center [11] indicate that only 11 percent of Americans believe that GM ingredients are present within most of the food they eat, and about half (48%) says that little, or none of the food they eat contain GM ingredients.

In June of 2016, a bill was introduced that would result in mandatory GMO labeling at the federal level, but would allow companies to choose the manner in which those ingredients were disclosed. The bill, the "National Bioengineered Food Disclosure Standard", passed quickly through the Senate and the House of Representatives, and was signed by President Obama on 29 July 2016.

1.1. The National Bioengineered Food Disclosure Standard

The National Bioengineered Food Disclosure Standard of 2016 (NBFDS) (7 U.S.C. 1639 et seq.) requires that all food products containing GM ingredients sold in the US disclose this fact to consumers. Passed as an amendment to the Agricultural Marketing Act of 1946 (7 U.S.C. 1621 et seq.), the NBFDS places responsibility for promulgating and enforcing GM food labeling within the USDA rather than the FDA, signaling that GM labeling is an issue of marketing and not of public health. However, disclosure labels will only be required for food that is subject to labeling requirements under the Federal Food, Drug and Cosmetic Act (21 U.S.C. 301 et seq.) which is under the purview of the FDA, and those regulated by the Federal Meat Inspection Act (21 U.S.C. 601 et seq.), Poultry Products Inspection Act (21 U.S.C. 451 et seq.), and the Egg Products Inspection Act (21 U.S.C. 1031 et seq.) which are overseen by the USDA. As a result, while most FDA-regulated food products will come within the scope of the regulations resulting from the NBFDS, the law excludes meat, eggs and poultry products that are regulated by USDA that do not contain a substantial proportion of ingredients subject to FDA jurisdiction. The NBFDS also gives the Secretary of Agriculture broad discretion in setting the standards for GM food labeling.

There are many aspects of the NBFDS that are controversial [12–16], including the definition of "bioengineered" food. Within the text of the NBFDS, a "bioengineered" food is defined as a food "(A) that contains genetic material that has been modified through in vitro recombinant deoxyribonucleic acid (DNA) techniques; and (B) for which the modification could not otherwise be obtained through conventional breeding or found in nature". By restricting the definition to include only those organisms modified through in vitro recombinant DNA techniques, foods derived from crops with genetic changes brought about through the use of gene silencing, gene editing, and mutation breeding would not be required to be labeled as "bioengineered". In addition, because the NBFDS specifies that a bioengineered food "contains" genetic material modified through in vitro recombinant DNA techniques, highly refined ingredients (HRIs) such as oils, sugars, syrups, and other products derived from genetically modified plants that are stripped of detectable DNA during processing would not need to be labeled as bioengineered foods. Of course, it is worth noting that it is possible for companies to exceed the minimum requirements set by the NBFDS.

An equally contentious provision permits companies to choose the method by which they disclose that their products contain GM ingredients. Companies may indicate that their products contain GM ingredients using text or a symbol on their product labels, or by printing an electronic or digital link such as a UPC (Universal Product Code) or QR (Quick Response) code on their labels that connects consumers to disclosure information published on a website. In the case of QR codes (or other digital links) accompanying on-package text such as "Scan here for more food information", would be required (§293 (a) (2) (D)). Moreover, if food manufacturers elect to use a QR code to disclose GM ingredients, it must be done in a "consistent and conspicuous manner, on the first product information page that appears for the product on a mobile device, Internet website, or other landing page" [17].

Because it offers the opportunity to provide information about GM ingredients to consumers who want it, while avoiding the potential stigma that might be attached to products as the result of printing prescribed text or a symbol on their labels [18], many food manufacturers are likely to choose the option of printing a QR code on their packaging to disclose the presence of GM ingredients in their products. Unconstrained by the limits of available space on product packaging, web-based "digital disclosures" also allow companies to present detailed, contextual information about the GM ingredients in their products, and to provide links to supporting science-based information. Web-based disclosure also allows companies to quickly update their associated product information in response to relevant changes in ingredients, sources, or suppliers [19].

1.2. SmartLabel

Many companies who intend to use QR codes to make disclosures about GM ingredients are likely to use the web-based SmartLabel platform (SmartLabel.org) (accessed on 1 April 2018) to do so. First launched in December 2015, the GMA and its associated Trading Partner Alliance created SmartLabel in an effort to provide consumers with more detailed information about food, beverage, personal care, household, and pet care products [20]. SmartLabel is promoted by the GMA and its member companies as a transparency initiative that "enables customers to get additional details about a wide range of food, beverage, pet care, household and personal care products" and promises to get people "answers to the questions they have on the products they purchase when they want that information" [21]. SmartLabel gives consumers access to detailed product information through a variety of avenues, including QR codes, web searches, a website, a phone number, an app, and a customer service desk. It does so by serving as a portal to product information that resides in a standardized format on each participating company's website. Despite appearing to be part of a uniform website, the information does not reside in a single database or website and is provided directly from individual companies to consumers and can therefore be directly edited or updated by the company [21].

By 2016, at least 30 of the largest food and beverage companies in the United States had already pledged to use the SmartLabel platform to provide detailed information about their products. As of September 2016, there were 1119 food products on the site from 13 different food manufacturers, including: Bumble Bee, Campbell's, The Coca Cola Company, ConAgra, Food for Life, General Mills, The Hershey Company, Kellogg, Kozy Shack, Land O' Lakes, Naked Bacon, PASCHA Chocolate, and Unilever. In 2016, the GMA projected that by the end of 2020, more than 60,000 food, beverage, personal care, pet care, and household products will have an associated SmartLabel, representing more than 80% of the products purchased in these categories [20,22]. To date, SmartLabel hosts more than 83,000 products and over 1000 brands [23].

1.3. Disclosure and Public Understanding of GM Science

The manner in which food manufacturers communicate about GM ingredients may be consequential for public understanding of the science of GM technology. From a marketing perspective, many manufacturers worry that disclosing that their products contain GM

ingredients could mistakenly signal consumers that the food is of lesser quality or is less safe than non-GM foods [24]. This reflects a longstanding food industry concern that consumers will interpret GM food labels as warnings [25,26] signaling that the products are of inferior quality or are unsafe, falsely alarming consumers [27], and leading them to reject products bearing GM labels [13,24,25,28,29]. Such concerns may be well-founded. Nearly 40% of Americans indicate that they believe that "foods with genetically modified ingredients are generally worse for health than foods with no genetically modified ingredients" [11], and consumers who consider GMOs to be risky to society are less likely to buy products with GM ingredients [19]. As a result, companies have both declined to voluntarily label their products as containing GM ingredients and have actively fought efforts at both the state and federal levels designed to impose mandatory labeling [30,31].

Furthermore, utilizing non-GMO labels represent a potential marketing opportunity for products that do not contain GM ingredients. To date, many companies have chosen to differentiate their products in the marketplace by claiming that those products contain no GM ingredients; nearly 16% of new US food and beverage products made non-GMO claims in 2015 [32]. Moreover, the Non-GMO Project (2017) claims that its Non-GMO Verified label is the fastest growing label within the natural products market, accounting for USD 19.2 billion in annual sales and more than 43,000 verified products for over 3000 brands [33]. Presumably, companies would not be willing to pay for the costs of third-party verification if they did not believe that they could command a price premium or increase market share by doing so. However, research suggests [34] that more than half of the Non-GMO Project Verified products are organic, and the USDA [35] already prohibits organic products from containing GM ingredients, and that many of the products do not contain ingredients that "have GE counterparts", and so could not have been derived from GM crops. Even so, many manufacturers have elected to label products as non-GMO, presumably to leverage consumer doubt in the safety of GM foods and encourage the purchase of foods by marketing them as non-GMO.

This type of one-way information transfer from authoritative sources to lay audiences is often referred to as the deficit model of science communication [36], where one-way communication is used to provide information on scientific and technical topics. Much has been written about the limitations of one-way science communication. The deficit model has been criticized, for example, for characterizing lay audiences as necessarily ignorant or lacking [37], and has been shown to be largely ineffective in terms of changing public opinion surrounding controversial science topics [38]. Even so, it remains widely used despite these limitations [38–41], even among groups attempting other models of public engagement [42]. Understanding when the deficit model is employed and the extent to which it is effective is a significant goal of science communication research [43].

How food manufacturers disclose GM ingredients may influence public perceptions of both GM foods and the science behind them. This is important because public perceptions of the science of GM as a technology are also likely to influence public acceptance of biomedical, environmental, and other non-food applications of biotechnology. There are four primary components of public understanding of GM technology that are focused on within the literature: public assessment of GM technology as a risk [44]; public understanding of the benefits, or potential benefits, of GM technology [45]; public knowledge (both subjective and objective) of GM processes and outcomes [28]; and public affect [46] toward GM technology, including public views on the acceptability [47] or morality [48] of GM applications.

Given the potential implications of disclosure for public understanding of GM technology and the importance of understanding when and if the deficit model is effective, it is advantageous to understand the communication landscape surrounding voluntary disclosure of GM ingredients and to examine the likely effect of disclosures, if any, on public understanding of GM technology. To that end, we examine how food manufacturers who use the SmartLabel platform started to communicate with consumers about GM ingredients, and we use an experimental design to test the effect of the most common characterizations

of GM technology used by these companies on perceptions of the risks and benefits of GM food.

1.4. Research Questions

Food manufacturers have the opportunity to communicate about GM ingredients in a variety of ways, and given that most Americans know very little about GM technology, this communication may be consequential for public understanding of GM. As such, our first research question is:

RQ1: How do food manufacturers that disclose GM ingredients on the Smart Label platform characterize those ingredients?

In an effort to explore the possible impacts of food manufacturers' disclosure on public understanding of GM, we ask:

RQ2: How does food manufacturers' characterizations of GM ingredients on Smart Label affect public understanding of the risks of GM technology?

RQ3: How do food manufacturers' characterizations of GM ingredients on Smart Label affect public understanding of the benefits of GM technology?

2. Materials and Methods

2.1. Study 1

To address RQ 1, we examined the information provided for each product contained within SmartLabel. We conducted a comprehensive search of the food products featured on the site in September 2016 (*n* = 1119) and created a database which coded and recorded the information provided on the site at the product-level. This database included the type of information provided about each product, including: company, brand, product name, product UPC code, and whether the product contained GM ingredients (if disclosed). Non-food products (e.g., non-edible household and personal care products) were excluded from this analysis.

Content that featured information about GM ingredients was retained and analyzed using an open-coding technique [49] to identify how food manufacturers characterized GM ingredients. Approximately 86 percent of products featured on SmartLabel (*n* = 963) had GMO disclosure statements, and a majority of these disclosure statements (*n* = 697, 72 percent) included one to five links to external webpages containing additional GM-related information. In an effort to more holistically capture how food manufacturers communicate about GM ingredients (and to understand the kinds of information to which consumers would likely be exposed), material from first-order external links were also retained for this analysis. This resulted in a total of 2123 documents that were qualitatively analyzed. Codes were attributed singularly at the document level. For example, if a company characterized GM ingredients as "safe" twice within the same statement, it would only be coded as "safe" once for the entire document. In addition to GM characterizations, we also noted any mention of scientific research or evidence for each document.

After codes were identified by the authors, an additional independent coder unaffiliated with the study was provided the codebook and coding instructions to ensure coding consistency and reduce researcher bias. This independent coder coded all of the collected documents. Coding results from all coders were combined and imported into SPSS and tested using Cohen's Kappa. Eight out of the twelve qualitative coding categories reached "perfect" or "almost perfect" agreement between coders in an initial test (as defined by a Cohen's Kappa score of greater than or equal to 0.80). All coding discrepancies within the remaining qualitative codes were resolved between coders, providing a final Cohen's Kappa for each qualitative code above 0.90.

2.2. Study 2

To examine the ramifications of the characterizations and names used for GM ingredients, and to answer research questions 2 and 3, we conducted a 2 × 3 post-test only experiment. Participants were randomly assigned to one of six conditions. The first ma-

nipulation consisted of how GM ingredients were characterized; specifically, we used the three most common characterizations utilized by food manufacturers in Study 1, including: GMOs are ubiquitous, GM ingredients are safe for human consumption and the environment, and GM crops improve yields (see exact stimuli text below). The second manipulation was the term used to refer to GM ingredients, both within the characterization *and* throughout the entire survey. Half of the participants had GM ingredients referred to as 'genetically modified food,' which is the term required for labeling in the European Union, was frequently used in the free-text field in Study 1, and is consistent with the terminology used by the Non-GMO project. Half had GM ingredients referred to as 'bioengineered food,' which is the term that will be required by the NBFDS. We measured the effect of these two labels and three characterizations on the perceived risks and anticipated benefits of GM food products. For a summary of experimental conditions, see Table 1.

Table 1. Experimental Conditions and Sample Sizes.

	Term			
Characterization	*Genetically Modified*		*Bioengineered*	
	Condition	*n*	Condition	*n*
Ubiquitous	1	125	4	125
Safe	2	125	5	125
Improves Yields	3	125	6	125

2.2.1. Study 2 Procedures

Data were collected using an online survey using the survey company Qualtrics. Participants were told that the study was designed to better understand their views on food and science. Pre-test survey items measured their basic understanding of how food is grown and produced, their preferences for food labels (e.g., what information they want on a food label), and some general questions about their perception of GM food, including how much they think they know about GM food, whether they think GM foods are currently sold in US supermarkets, and if they support the labeling of GM ingredients on food packages. Following these initial questions, participants were told "The remaining questions will ask you your opinion about [genetically modified/bioengineered] food. [Genetically modified/bioengineered] food is food that has been produced, at least in part, through [genetic modification/bioengineering]". Participants then read one of six scripts that differed according to the description and name for GM ingredients. Participants were either told that GM ingredients were ubiquitous ("Genetically modified foods have been grown widely in agriculture for more than 20 years, and it is estimated that 70–80% of foods in the U.S. have ingredients produced from genetically modified crops"), that they are safe ("Genetically modified foods are as safe as comparable, non-genetically modified food"), or that they can improve crop yield ("Genetically modified food allows farmers to grow more food using less land").

Additional conditions were created by manipulating the term used to refer to GM ingredients. First, each use of the term 'genetically modified' or 'GMO' in the above characterizations was replaced with the term 'bioengineered' for half of the participants in each characterization condition. Second, the term used to refer to GM ingredients in the stimuli text was also used throughout the survey protocol. That is, participants in the 'genetically modified' condition would see that term repeatedly throughout the survey (and would not see the term 'bioengineered'), and participants in the 'bioengineered' condition would see that term used repeatedly throughout the survey (and would not see the term 'genetically modified').

2.2.2. Study 2 Participants

Data were collected from a random sample of US adults (*n* = 750) to obtain 125 participants per experimental condition. In line with our use of a Qualtrics survey panel, the population from which we recruited included those living in the United States, 18 years

of age or older, who had previously agreed to participate in survey research either with Qualtrics or one of their contracted partners. Participants for this study were 50.5% female and 49.5% male, mostly white (69.6%) and non-Hispanic (89.6%). Participant ages ranged from 18–24 (18%) to 85 or older (0.3%), and the average age was 35–44. The most common education level was a high school diploma or equivalent (37.1%), followed by some college (21.1%), a four-year degree (16.5%), a graduate or professional degree (11.8%), two-year degree (9.7%), and less than high school (3.7%). A quota method was used to ensure semi-equal representation of race (69.6% white, 30.4% non-white) and biological sex (ranging from 41–56%, respectively) within each condition.

2.2.3. Study 2 Measures

Dependent variables measured in this study include perceived risks of GM technology and perceived benefits of GM technology. Risks and benefits were measured using survey questions modified from the Pew Research Center [11]. To measure perceived risks, participants were asked to indicate how likely it is, on a 7-point Likert scale, that [genetically modified/bioengineered foods]: will create problems for the environment in the future; have already created problems for the environment; will lead to health problems for the population as a whole in the future; have already led to health problems for the population as a whole. Response options included: extremely likely, moderately likely, slightly likely, neither likely nor unlikely, slightly unlikely, moderately unlikely, and extremely likely. As a scale, all four risk items were highly reliable ($\alpha = 0.916$) and thus were averaged together into a single 'risks' variable (M = 4.09, SD = 1.042).

To measure perceived benefits, participants were asked the likelihood, on a 7-point Likert scale, that [genetically modified/bioengineered foods]: will increase the global food supply in the future; have already increased the global food supply; will lead to more affordably priced food in the future; have already led to more affordably priced food; will benefit the environment in the future; have already benefited the environment. Response options included: extremely likely, moderately likely, slightly likely, neither likely nor unlikely, slightly unlikely, moderately unlikely, and extremely likely. As a scale, all six benefits items had high reliability ($\alpha = 0.882$), and thus were averaged together to create a single 'benefits' variable (M = 4.846, SD = 1.185). Risks and benefits items were asked together and randomized to avoid priming effects.

Three additional independent variables were measured for this study, including self-reported knowledge, objective knowledge, and moral assessment of GM food [1]. To self-report their knowledge, participants were asked "About how much do you know about [genetically modified/bioengineered] foods?" using a 5-point Likert scale (nothing at all (1), very little (2), some (3), a fair amount (4), a great deal (5)) (M = 2.81, SD = 1.732).

To measure objective knowledge, participants were shown 10 statements about GM technology and asked to indicate how true the statement is using the following scale: definitely true, probably true, might or might not, probably false, or definitely false. False statements included: "Ordinary tomatoes do not contain genes, while [genetically modified/bioengineered] tomatoes do", "by eating [genetically modified/bioengineered] fruit, a person's genes could also become modified", "tomatoes [genetically modified/bioengineered] with genes from a catfish would probably taste fishy", "most [genetically modified/bioengineered] plants are made so that they cannot reproduce", "sugar made from [genetically modified/bioengineered] sugar beets is different from sugar made from regular sugar beets", and "[genetically modified/bioengineered] crops are harmful to bees". True statements: "It is possible to transfer animal genes to plants", "pollen from [genetically modified/bioengineered] corn was shown to kill butterfly larva in a laboratory", "some [genetically modified/bioengineered] crops are created using radiation to create genetic mutations", and "most soybeans grown in the US are a [genetically modified/bioengineered] variety". Each participant was then scored based on the correct answers for each statement, earning 2 points for correctly selecting "definitely" (true/false), 1 point for correctly "probably" (true/false), and 0 points for selecting "might or might not", −1 point for incor-

rectly selecting "probably" (true/false) and −2 points for incorrectly selecting "definitely" (true/false). A summative knowledge score was then calculated for each participant, which could range from −20 (getting all items incorrect *and* being definite in their answer) to +20 (getting all items correct *and* being definite in their answer) (M = 0.62, SD = 3.837). The lowest score earned in our sample was −11, the highest score earned was 14.

To measure moral assessment, participants were shown a list of eight moral statements [50] about GM foods and asked to indicate, using a 7-point Likert scale, the extent to which they agreed or disagreed. Scale options included: strongly agree, agree, somewhat agree, neither agree nor disagree, somewhat disagree, disagree, and strongly disagree. Statements shown to participants included: We are able to use [GM/Bioengineered] foods to do moral good; Genetic modification of food is moving too rapidly; [Genetically modified/bioengineered] foods will improve our quality of life; Research involving [GM/Bioengineered] foods is in conflict with my religious or moral views; we are able to use [genetically modified foods/biotechnology] to do moral good; The use of [genetically modified foods/biotechnology] is blurring the line between God and man; [GM/Bioengineered] foods are immoral; and [GM/Bioengineered] foods are unethical. The scale was reliable (α = 0.787) and the measures combined into a single 'morality' score for each participant (M = 4.09, SD = 1.042), such that a higher morality score indicates a higher moral assessment of GM foods.

3. Results

3.1. Study 1

RQ1 asked: How do food manufacturers that disclose GM ingredients on the Smart Label platform characterize those ingredients? We looked at two factors: how companies defined what it meant for a food product to be genetically modified, and what term food manufacturers used when naming GM ingredients.

Within the 2123 documents coded, 12 characterizations of GM ingredients were identified, which were then mapped onto the product for which the information was included. For example, if a product included two external links to different sites that discussed GM ingredients, the codes for both of those sites were integrated. As such, the results presented here are discussed at the product-level. The characterizations of GM ingredients and GM crops present in the data were, from most to least common: (1) GMOs are ubiquitous in our food system and are in most of the food we eat, (2) GM ingredients are safe for human consumption and for the environment, (3) GM improves crop yields, (4) GM crops are comparable to non-GM crops, (5) GM is not a new technology, (6) GM crops offer economic benefits, (7) GM crops are of higher quality or desirability than non-GM crops, (8) GM crops are distinct from non-GM crops, (9) GM ingredients are a contaminant to be avoided, (10) GM crops are more sustainable and offer environmental benefits, (11) GM crops are nutritious, (12) GM crops are not risky. For more information, including intercoder reliability statistics and examples of each characterization, see Table 2.

These characterizations were not mutually exclusive, as food manufactures often used more than one to portray GM crops and ingredients. Products that included a characterization included at least one (*n* = 93), and as many as ten (*n* = 1). Approximately 23 percent of products that included a GM disclosure statement within SmartLabel did not characterize those ingredients in any way (*n* = 221). The median number of characterizations included per product was seven. Notably, claims that GM crops are safe for human consumption and claims that GM crops are not risky may be similar. However, we distinguish them here because in the former, food manufacturers specifically used the term "safe", while for the latter manufacturers used the term "not risky". While there is an argument to be made that these terms should be coded together, the terms "safe" and "risky" could arguably evoke different responses from consumers. As such, we kept them separate.

Table 2. Summary of GM Characterizations.

Code	Definition/Example	Number of Products	Cohen's Kappa
Ubiquitous	GMOs are ubiquitous in our food system and are in most of the food we eat; "At least 70−80% of the foods we eat contain genetically modified ingredients"	648	0.942
Safe	GM ingredients are safe for human consumption and for the environment; "Foods from genetically engineered plant varieties marketed to date are as safe as comparable, non-genetically engineered foods"	582	1.000
Improves Yields	GM technology improves crop yields; "GM technology allows farmers to generate more stable—and sometimes higher—yields"	582	0.942
Comparable to non-GM crops	GM crops are comparable to non-GM crops along some dimension; "GM food is as safe and nutritious as food that is non-gm"	569	0.968
Not New	GM is a technology that is not new or novel; "GM has been around for the past 20 years"	569	1.000
Economical	GM crops are more economical than non-GM crops in that they cost less to produce and, thus, can be sold at a lower price to consumers; "GM technology helps reduce the price of crops used for food . . . by as much as 15–30%"	551	0.969
High Quality	GM crops are of higher quality or desirability than non-GM crops; "GM adds specific desirable traits from one plant or microorganism to a food plant"	535	0.966
Distinct	GM crops are different from non-GM crops; "GM is different from traditional plant breeding"	82	1.000
Contaminate	GM ingredients are a contaminant to be avoided; "Identity Preservation requires practices and processes for controlling contamination from at-risk GMO inputs and ingredients"	67	1.000
Sustainable	GM crops are more sustainable and better for the environment than non-GM crops; "Examples of GM efforts include those designed to allow crops to use less water or be grown on less land"	45	1.000
Nutritious	Foods produced with GM crops are nutritious; "Foods that contain GM ingredients are nutritious"	18	1.000
Not Risky	GM crops are not risky to human health or the environment; "There is no health risk associated with GM foods or ingredients"	17	1.000

Most of these characterizations are positive descriptors. Claims that GMOs are ubiquitous in our food supply, safe, improve crop yields, are comparable to non-GM crops, are a well-known technology, provide economic benefits, improve crop characteristics, aid in sustainability, and are nutritious, are fundamentally positive. These characterizations extol the benefits of GM crops to the environment, health, and economy, and assure consumers that they are fundamentally no different from conventionally bred crops. By contrast, claiming that GM crops and ingredients are a contaminant is arguably negative, in that this implies that GM crops are foreign substances that ought to be avoided.

We also examined what food manufacturers called GM ingredients. Four terms related to GM ingredients were used by food manufacturers on the SmartLabel platform: GMO, genetic engineering, genetically modified, and biotechnology. Because the SmartLabel standards required manufacturers to use the term genetically engineered when disclosing GM ingredients and to do so under the heading GMO Disclosure Statement, all of the 963 products providing GMO disclosure were coded as using both terms. The requirement to use the term genetic engineering was also consistent with the extant Vermont's Act 120, which required labeling of GM foods, effective 1 July 2016. This law, which was ultimately preempted by the NBFDS required manufacturers to "label the package offered

for retail sale, with clear and conspicuous words 'produced with genetic engineering'" [51]. It is also in line with the FDA's preferred use of the term genetic engineering rather than genetic modification, which it considers to be inexact [52]. However, this is in contrast to labeling regulations enforced by the European Commission [53], which requires that when pre-packaged food products contain >0.9% GMO ingredients, the list of ingredients must indicate "genetically modified" or "produced from genetically modified [name of the organism]. It is also contrary to the GMA's own recommendation to the USDA that the term "bioengineered" be adopted [21]. In fact, the NBFDS now specifies that the term "bioengineered" be used to identify such products, beginning 1 January 2022

In addition to using the required terms GMO and genetically engineered in their disclosures, food manufacturers were provided a "free text field" where they were free to use alternative terms. Those choosing to do so used the terms genetically modified or biotechnology. The term genetically modified is the third most commonly used term, used as part of disclosures for 677 products, equaling a total of 60 percent of total number of food products on the site and 70 percent of products that included a GM disclosure statement. Finally, biotechnology was the least used term. It was used for only 113 of the products on the site, which is 12 percent of the products that include a GMO disclosure statement. Importantly, use of these terms was not mutually exclusive. Out of the 113 products that use the term biotechnology, 90, or 79.6 percent, also use the term genetically modified.

3.2. Study 2

RQ2 asked: How do food manufacturers' characterizations of GM ingredients on Smart Label affect public understanding of the risks of GM technology? A Two-Way ANOVA was used to compare the main effects of 'characterization' and 'term', and the interaction effect of characterization and term on perceived risks of GM foods. There was no significant effect of characterization ($F_{(2, 744)} = 1.195$, $p = 0.303$) or term used ($F_{(1, 744)} = 0.255$, $p = 0.614$), and no interaction effect between the two ($F_{(2744)} = 0.006$, $p = 0.994$).

RQ3 asked: How does food manufacturers' characterizations of GM ingredients on Smart Label affect public understanding of the benefits of GM technology? A Two-Way ANOVA was run to compare the main effects of 'characterization' and 'term', and the interaction effect of characterization and term on perceived benefits of GM foods. There was no significant effect of characterization ($F_{(2, 744)} = 0.714$, $p = 0.490$) or term used ($F_{(1, 744)} = 0.024$, $p = 0.878$), and no interaction effect between the two ($F_{(2744)} = 1.275$, $p = 0.280$).

Study 2 Post hoc Analysis

Because we did not observe an effect between experimental conditions, we combined data from all conditions and ran two post hoc multiple linear regression analyses across all participants using the independent variables noted above to examine the extent to which those variables (self-reported knowledge, objective knowledge, and morality assessment) predict perceived risks and benefits of GM foods. The regression predicting perceived risks of GM foods was significant ($F_{(3744)} = 165.276$, $p < 0.001$), with an R^2 of 0.400, indicating that the three variables predict a large portion of the variance in perceived risks. Specifically, morality assessment ($B = -0.586$, $p < 0.001$) [2] and objective knowledge ($B = -0.024$, $p < 0.05$) negatively predict perceived risks, while self-reported knowledge ($B = 0.119$, $p < 0.001$) positively predicts perceived risks. The regression predicting perceived benefits of GM foods was also significant ($F_{(3744)} = 61.304$, $p < 0.001$) with an R^2 of 0.198, and showed the opposite pattern for morality assessment and self-report knowledge. Specifically, morality assessment ($B = 0.409$, $p < 0.001$) and self-report knowledge ($B = 0.253$, $p < 0.001$) positively predict perceived benefits. By contrast, objective knowledge ($B = -0.149$, $p < 0.001$) negatively predicts perceived benefits. For a summary of regression statistics for both post hoc analyses, see Table 3.

Table 3. Post hoc Regression Analyses.

	Unstandardized B	*Standardized B*	*p*	R^2
Model 1: Perceived Risks				
Morality	−0.810	−0.586	<0.001	
Self-Report Knowledge	0.150	0.119	<0.001	
Objective Knowledge	−0.063	−0.024	<0.05	
				0.400
Model 2: Perceived Benefits				
Morality	0.465	0.409	<0.001	
Self-Report Knowledge	0.262	0.253	<0.001	
Objective Knowledge	−0.046	−0.149	<0.001	
				0.198

4. Discussion

Food labels are likely to be a key avenue through which consumers are exposed to information about GM technology, which may, in turn, affect public perception. Study 1 was designed to examine how food manufacturers on the Smart Label website communicate about GM ingredients to consumers, as food manufacturers are likely to be the key avenue through which consumers are exposed to GM information. We found that the primary characterization of GM foods is that GM ingredients are ubiquitous, safe, and improves crop yields. We also found that various terms were used to refer to GM foods, including 'genetically modified' and 'biotechnology'. Study 2 was designed to examine what effect, if any, these characterizations and labels have on public perceptions of GM risks and benefits. The results suggest that there are no significant differences between using the terms genetically "modified" and "bioengineered" in perceptions of the risks or benefits of genetically modified foods. Similarly, there is no differential effect of characterizing them as "safe", "ubiquitous", or as "improving crop yields".

Given that term and description variations did not have an effect on public perceptions of the risks and benefits of GM foods, we combined data across conditions to examine whether three independent variables (morality assessment, self-report knowledge, and objective knowledge) predicted perceived risks and benefits. Those who deem GM technology as moral typically see GM foods as less risky and more beneficial for human health and the environment. Those who have higher self-reported knowledge see GM foods as both riskier and more beneficial. Those who have higher objective knowledge of GM technology see GM foods as less risky and less beneficial for human health and the environment. That is, those who think they know a lot about GM foods see them as high risk, high benefit, while those who objectively know more see GM foods as low risk, low benefit. Importantly, self-reported knowledge and objective knowledge measures were not significantly correlated (t = −0.060, p = 0.101), indicating that there is little to no relationship between what people *think* they know and what they actually know about GM technology.

The deficit model of science communication refers to the use of one-way communication from experts to lay audiences, with the ultimate goal of filling a gap in lay audience understanding of a scientific topic [36,39,40]. The deficit model is likely to be widely used to communicate with consumers about GM food, especially given that knowledge of GM food, and GM technology more generally, is fairly low in the United States [9]. Utilizing food labels to communicate with consumers about GM technology is increasingly common, and will arguably be the primary way consumers are exposed to GM information given laws like the National Bioengineered Food Disclosure Standard. Importantly however, the deficit model has been shown to be ineffective for many science topics [40,54], including controversial science topics similar to GM foods (such as climate change). Results of the current study echo previous work and suggests that communicating with consumers about the details of GM technology (in our case, using varying terms and descriptions for GM food) via food labels using the one-way communication strategies common to the

deficit model is likely to be an ineffective method of either informing or influencing public perceptions of the risks and benefits of GM technology.

Public engagement surrounding GM technology is vital for both public acceptance and support and for negotiating potential applications of the technology. The current study suggests that the label and description food manufacturers use on Smart Label to communicate with consumers in the United States about GM food may be inconsequential for public understanding of the risks and benefits of GM foods. This might be because a large part of the variance we observed in our post hoc analyses for risk and benefits perceptions was explained by likely pre-existing moral assessments of GM technology. While information transfer using food labels may aid in filling gaps in objective knowledge (also a significant predictor), it is unlikely to address consumers' moral evaluations of the technology. Other forms of public engagement that provide opportunities to address the ethical and moral implications of science and technology, like public participation models have been shown to be more fruitful than one-way deficit model approaches [55,56].

Study 2 did not show an effect of disclosure characteristics on public perception of the risks and benefits of GM food. Even so, there may still be other relevant concerns regarding the labeling of GM foods and public understanding of GM technology. For example, decisions concerning what ingredients qualify as "bioengineered" and must therefore be labeled may significantly influence consumer views of the extent GM ingredients are used in the US food supply. Specifically, excluding from mandatory labeling, ingredients without detectable modified genetic material such as refined oils, syrups, and sugars derived from GM crops, and those genetically modified through the use of mutation breeding, gene silencing, and gene editing technologies, significantly reduces the number of products that would be required to be labeled "bioengineered". These exclusions may give the misleading impression that far more food products are comprised of ingredients derived exclusively from "conventionally bred" organisms (suggesting that those products are Non-GMO) than is actually the case. Moreover, if manufacturers must only disclose the ingredients derived from agricultural products created through in vitro recombinant DNA techniques, it is possible that consumers may only be introduced to this very specific technology rather than to the broader science of GM.

Importantly, the successful marketing of a food product and fostering broad public understanding of GM technology are still largely in conflict for foods that claim to be free of GM ingredients. For example, the current scientific consensus is that GM foods and ingredients are as safe as those derived from conventional crops [57]. Yet, rather than include GM ingredients in their products and convey this consensus message to the public through their disclosures, marketers may find it more profitable to capitalize on consumer perceptions that GM foods are risky, and on their willingness to pay more for non-GM products (Moon & Balasubramanian, 2003). While the specific terms and characterizations used to disclose the presence of GM ingredients may have little effect on public perception of the risks and benefits of GM food (as indicated in the current study), the collective result of non-GMO marketing decisions may reinforce consumer perceptions that GM foods are to be avoided. This possibility is further supported by evidence that food labels impact consumer behavior [58] and that some consumers—namely, those who already view GM foods as risky—are more likely than others to check food labels for GM ingredients [19]. Future work should examine these dynamics.

As with any study, there are limitations to note. First, our significant result came from post hoc analyses. Future work should continue to examine the relationship between the variables reported here (self-report knowledge, objective knowledge, and moral assessment) and risk perceptions. Additionally, there is ample opportunity for more work that examines the ramifications of the mass marketing non-GMO foods, as noted above. Second, our sample is not a representative sample of the United States. As such, the results found here, including our post hoc analyses, may not be representative of all consumers in the United States. Future research should explore the extent to which our experimental and post hoc results apply to other populations, including areas like Europe where existing attitudes

regarding GM foods tend to be more negative [59]. Third and finally, because we were primarily interested in public understanding of GM food as a scientific issue, this study focused primarily on the risk and benefit perceptions of GM food. It did not examine other variables that might be of interest (e.g., willingness to purchase a food product based on disclosure methods). As such, future work will be necessary to more fully inform food labeling practices and the consequences therein.

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Notes

1   As noted above, prior literature suggests that knowledge of a risk [60] and affective judgements about GM technology, including moral assessments [50,61], may influence risk and benefit perceptions. We collected these data as control variables in an effort to isolate the effect of our experimental conditions.

2   Standardized coefficients are reported in-text, as the independent variables had different measurement scales. Both the standardized and unstandardized coefficients are available in Table 3.

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