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Sociotechnical imaginaries of gene editing in food and agriculture: A comparative content analysis of mass media in the United States, New Zealand, Japan, the Netherlands, and Canada

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Abstract

Sociotechnical imaginaries of gene editing in food and agriculture reflect and shape culturally particular understandings of what role technology should play in an ideal agrifood future. This study employs a comparative media content analysis to identify sociotechnical imaginaries of agricultural gene editing and the actors who perform them in five countries with contrasting regulatory and cultural contexts: Canada, Japan, New Zealand, the Netherlands, and the United States. We find that news media in these countries reinforce a predominantly positive portrayal of the technology's future, although variations in which imaginaries are most mobilized exist based on the regulatory status of gene editing and unique histories of civil society engagement around biotechnology in each country. We argue that by granting legitimacy to some narratives over others, the media supports gene editing as a desirable and necessary component of future agrifood systems, thereby limiting consideration of broader issues related to the technology's development and application.

Keywords

food and agriculture, gene editing, governance, media representations

1. Introduction

The use of gene editing tools such as CRISPR/Cas9 in agriculture has increased tremendously since 2013. Proponents of biotechnology promise diverse benefits for consumers, producers, and the environment, such as nutritional enhancements for food and greater stress tolerance for plants (Shukla-Jones et al., 2018). However, gene editing in agriculture and food (GEAF) also poses public acceptance challenges due to its association with genetically modified organisms (GMOs), scientific complexity, and social and ethical concerns (Wirz et al., 2020). To deflect potential public controversy, proponents of GEAF are developing and communicating sociotechnical imaginaries that point to its future benefits (Bain et al., 2020). Sociotechnical imaginaries describe "the implicit assumptions, values and visions" (Macnaghten et al., 2005: 13) that proponents assert concerning what collective futures should emerge and the central role of sociotechnical assemblages, such as gene editing, in that imagined future. The evolving landscape surrounding the development and regulation of gene editing offers an opportunity to examine the imaginaries impacting its development.

National media coverage of technologies influences which imaginaries become institutionally stabilized by granting legitimacy to some narratives over others and shaping public perception of ideal agrifood systems (Bearth et al., 2022; Vicente and Dias-Trindade, 2021). The prevalence of particular imaginaries in the media is shaped by cultural understandings of progress, innovation, uncertainty, and what counts as evidence. Media attention cycles (Downs, 1972), issue framings (Entman, 1993), and cited actors are themselves shaped by underlying social mechanisms, such as power relations, advocacy activities by interest groups, policy arenas in which debates take place, and values of decision-making institutions (Kalaitzandonakes et al., 2004; Nisbet and Huge, 2006). These social mechanisms differ between countries, especially for contentious policy issues such as biotechnology, due to unique risk cultures, regulatory contexts, and national identities (Ely et al., 2022; Jasanoff, 1995; Nisbet and Huge, 2006). Comparing how national debates around issues such as biotechnology differ can provide important insights into ongoing, wider political realignments and the cultural specificities that influence policymaking (Jasanoff, 2004). However, limited work has comparatively explored how sociotechnical imaginaries of GEAF are expressed in the media in countries with contrasting regulatory and cultural contexts.

This article aims to fill this gap by undertaking a comparative study on sociotechnical imaginaries of GEAF and the actors who perform them in mass media. We use content analysis to answer four research questions: (1) what are the trends in attention paid to the topic of gene editing in news media over time?; (2) which sociotechnical imaginaries of GEAF are represented in national news media in the United States, Canada, Japan, Netherlands, and New Zealand?; (3) which actors express these sociotechnical imaginaries across these differing country contexts?; and (4) how are regulatory issues related to GEAF described in each country's media?

Building on our media content analysis, we argue that by highlighting predominantly supportive voices and positive imaginaries, the media in all these countries support gene editing as a desirable and necessary component of future agrifood systems, thereby limiting consideration of broader issues related to the development and application of this technology. This research contributes to recent efforts to connect the concept of sociotechnical imaginaries to media framing and thereby explicate the public dimension of the institutionalization of imaginaries (Vicente and Dias-Trindade, 2021). We also contribute to the emergent scholarship that applies science and technology studies concepts to analyze agrifood technologies and futures (Gugganig et al., 2023).

2. Literature review

Sociotechnical imaginaries, or forward-looking visions for the future, are not problem frames or policy agendas: they "are collective, durable, and capable of being performed; yet, they are temporally situated and culturally particular" (Jasanoff, 2015a: 19). Jasanoff (2015b) proposes a four-phase life cycle for sociotechnical imaginaries: origins, embedding, resistance, and expansion. In the origins phase, imaginaries emerge from various sources like individual dreams and perceptions, corporate visions, or societal aspirations. Hence, imaginaries do not just comprise future visions but also underlying assumptions and values. In the embedding phase, they translate into material, cultures, and institutional realities, creating identities and routines. The resistance phase highlights challenges faced by imaginaries from competing ideas or social movements, while the expansion phase explores how these imaginaries become universal and travel across different contexts and territories, shaping global sociotechnical landscapes. The imaginaries concept has been used to analyze energy futures (Jasanoff and Kim, 2013), technological developments in transportation (Braun and Randell, 2020), and biotechnology in agriculture and food (Meghani, 2017; Smith, 2015). Although imaginaries present in media coverage can potentially provide important hints to what public perception of new technology might be—information important to decision-makers and industry—research on sociotechnical imaginaries of gene editing is limited.

Existing studies on this topic demonstrate the considerable embedding of the imaginaries expressed by proponents in shaping national social structures that guide the trajectory of GEAF. Middelveld and Macnaghten (2021), for example, interviewed agricultural researchers and delegates of animal breeding firms in the Netherlands, finding three interlocking imaginaries for gene editing for animals that prioritize reflexivity, responsiveness, and inclusion to varying degrees. In another context, Yamaguchi (2020) studied discourses within Japanese science policy texts, arguing that the futures described within these documents work to form sociotechnical networks that support GEAF's development. In the United States, Bain et al. (2020) analyzed public comments submitted to the FDA docket "Genome Editing in New Plant Varieties Used for Food" and found three dominant imaginaries are being constructed and communicated by proponents: (1) that gene editing is not the same as (and is better than) GMO; (2) that gene editing will deliver a new climate-adapted Green Revolution; and (3) that gene editing will democratize access to and use of agricultural biotechnology. The imaginaries identified in each of these studies, which are clearly situated in their specific cultural, social, and regulatory contexts, have been or are likely to become institutionally stabilized.

Sociotechnical imaginaries are often contested, as actors who hold counterhegemonic views on the appropriate relationship between a particular technology and society may actively strive to disrupt and challenge dominant visions of the future (Kim, 2015; Longhurst and Chilvers, 2019; Smith and Tidwell, 2016). In the case of gene editing, critics have challenged proponents' dominant imaginaries by constructing competing "counter" or alternative imaginaries that question the technology's safety and necessity. Some opponents have argued that gene editing *is* the same as GMOs because "naturalness" is not determined by the final product but by the process used to develop it. These actors also claim that the environmental release of gene-edited organisms may have unpredictable ecological consequences (Helliwell et al., 2017). Skeptics have also questioned the problem framings that underlie proponents' food security, sustainability, and democratization discourses; they point out that mischaracterization of root cause problems limits the solutions that are perceived as feasible and appropriate (Montenegro de Wit, 2022). Tensions regarding the role of gene editing in future food systems exist both within and between groups, with actors on both sides of the debate expressing nuanced views about appropriate governance (Selfa et al., 2021).

Both proponents and critics communicate imaginaries through public-facing documents, such as whitepapers and press releases. When direct communications are picked up by the news media, they introduce the broader public to novel technologies and scientific innovations (Marks et al., 2003). Research on agenda setting shows that the volume of media coverage allotted to biotechnology issues correlates with its salience on the public agenda (Kalaitzandonakes et al., 2004). Media framing research has found that how the news media frames an issue, or makes specific aspects of it more prominent than others, also promotes particular evaluations among readers (Entman, 1993). For example, increases in negative media coverage of biotechnology in the early 2000s were correlated with subsequent increases in negative public opinion (Nisbet and Lewenstein, 2002). Thus, media framing of technologies can influence whether they are embedded, resisted, or broadly adopted (McCluskey et al., 2016). Recognizing issue-specific frames in media contexts as starting points when examining sociotechnical imaginaries, we ask how actors shape the particular story and incorporate their expectations of GEAF.

Media coverage of GMOs has primarily focused on social risks such as public safety, ethical issues, or lack of labeling (McCluskey et al., 2016). Given the low level of public knowledge about new genetic breeding techniques, such as GEAF, (Debucquet et al., 2020), these previous characterizations of issues related to associated technologies are likely to influence how issues of GEAF are interpreted by the lay public. These characterizations shape the discursive strategies that actors, including journalists, use to advance imaginaries that either build on or challenge certain attributes, themes, and tensions with which the public is already familiar. Given the focus that some proponents of GEAF are placing on its democratizing potential (Bain et al., 2020), media coverage of gene editing may also feature a broader range of actors and assumptions, which can also influence how issues are framed and consequently understood. For example, one study that examined media portrayal of GEAF in the United States and the EU found that news coverage in both contexts is largely positive and emphasizes frames related to social progress and governance (Dahlstrom et al., 2022).

News coverage of genetic engineering in most Western countries has historically been dominated by academics and industry spokespersons, while environmentalists and consumer protection groups receive comparatively less airtime (Ashwell, 2011; Kohring and Görke, 2000; Nisbet and Lewenstein, 2002). In past media coverage of biotechnology in the United States, for example, sources affiliated with government and industry appear more often, likely due to their access to resources and close relationships with the media (Nisbet and Lewenstein, 2002). Because these actor groups typically emphasize agricultural biotechnology's benefits (Lewison, 2007), journalists can restrict the scope of a debate by highlighting certain points of view while marginalizing others, including those of critical actors who seek to challenge the status quo (Binderkrantz et al., 2020).

3. Case study country background

The five countries for this comparative analysis were chosen based on their distinct governance approaches to agricultural biotechnology and their unique histories of civil society engagement around GMOs. We expect that efforts to build social license and governance frameworks for GEAF will be promoted and contested by different constellations of actors in each country, resulting in different imaginaries permeating media coverage. The case study countries also exist along a spectrum in terms of whether the regulatory status of gene-edited crops has been defined, which provides an opportunity to analyze how policy decisions impact both news volume and content.

United States

The United States grows the largest area of GM crops worldwide (ISAAA, 2019). Despite this, public sentiment toward GMOs remains mixed (Funk, 2020). The American regulatory environment is characterized by strong government support for the biotech industry (Meghani and Kuzma, 2011). Early policy decisions about biotechnology in the United States addressed uncertainty by narrowly defining the risks of genetic engineering in ways which constrained the debate to discussion of physical hazards, illustrating regulators' preference for appealing to objective evidence and scientific principles when developing and justifying policies (Jasanoff, 1995; Kinchy, 2012).

Under the United States Department of Agriculture's (USDA) revised 2021 biotechnology regulations, gene-edited foods do not need to be regulated or labeled if the end product is nontransgenic. This decision has been met with strong backlash from environmental and consumer advocacy groups, who are concerned that a product-based paradigm ignores the potential risks of the gene editing process and undermines consumer choice (Gordon et al., 2021). As with GMOs, American citizens remain divided on their perceptions of this new technology (Cummings and Peters, 2022).

New Zealand

New Zealand has an extremely stringent regulatory regime for GMOs, applying a process-driven framework that defines any organism where the genetic material has been modified by in vitro techniques as a GMO. No GM crops are currently grown in the country, in part because commodity crops which account for the majority of GM plantings worldwide are not widely grown in New Zealand (Fritsche et al., 2018). Moreover, because developing and gaining regulatory approval for GM versions of important specialty crops is costly and time-consuming, genetic engineering has been discounted by critics as irrelevant and unnecessary for the country's agricultural sector, which is a strong driver of New Zealand's economy (Royal Society Te Aparangi, 2019).

While a 2013 decision by the New Zealand Environmental Protection Authority (EPA) concluded that products of non-transgenic gene editing should not be regulated as GMOs, the decision was overturned by the High Court in 2014 (Kershen, 2015). Thus, New Zealand became the first country to explicitly rule that gene editing is a form of genetic modification and must be regulated as such. Public opinion strongly favors New Zealand remaining "gene editing free" (Whitehead, 2018), with some opponents concerned that growing and exporting gene- edited crops would harm the national economy by undermining New Zealand's reputation for sustainable and high-quality agricultural products. However, many scientists and businesses argue that the technology is necessary to address a host of problems confronting agriculture, especially the impacts of climate change (Fritsche et al., 2018).

Netherlands

The EU largely determines biotechnology regulation in the Netherlands. After a de facto moratorium from 1999 to 2004, authorization of new GM crops or products now requires a strict assessment by the European Food Safety Agency. As of 2023, GM technology is applied for research purposes only in the Netherlands and GM products must be labeled as such. At the same time, the country is a significant global exporter of seeds and young plants, so gene editing techniques play an important role in science and industry.

Tensions exist between Dutch and EU perspectives toward the regulation of GEAF. While in 2017, the newly elected Dutch government favored the use of new breeding techniques, including CRISPR/Cas9, the July 2018 European Court of Justice (ECJ) decision determined that products of gene editing should be regulated as GMOs. The discontent of the plant breeding and biotech industries, and conventional farmers who consider gene-edited crops advantageous, has triggered discussions about the suitability of the GMO directive at national and European levels.

Overall, GEAF is not controversial in the Netherlands; industry, scientists, and political groups all perceive the EU regulation to be problematic, hindering innovation and progress toward a resilient and sustainable agrifood sector (van der Berg et al., 2021). Dutch citizens are also largely supportive of the technology's use, although they do expect minimum safety requirements (COGEM, 2019).

Japan

Japan takes a precautionary approach toward modern biotechnology, with several statutes in place to regulate it. Despite this cautious approach, Japan has the second-largest number of approved biotech crop events in the world (ISAAA, 2019). While it is legal to plant GM crops in Japan, there are currently no commercial plantings, partly due to strong consumer skepticism regarding GMO safety and local ordinances that restrict commercial plantings.

In 2019, the Japanese government issued a ruling which states that only gene-edited organisms with foreign genes will be regulated. Following this notification, the Food Sanitation Commission of Pharmaceutical Affairs and Food Sanitation Council published guidance stating that the insertion of one to a few bases would not be considered as producing GMOs.

The general public in Japan has more favorable attitudes toward GEAF than GMOs (Kato-Nitta et al., 2019), although some stakeholders have identified several key issues. These include the need for clear and uniform regulations to replace the current patchwork of national and local standards and the development of crops that are perceived to have high added value for consumers, such as foods with health benefits (Spök et al., 2022).

Canada

Canada is the fourth-largest producer of GM crops in the world (ISAAA, 2019). Two agencies are responsible for gene editing's regulation and oversight: Health Canada, which develops food safety policies and standards, and the Canadian Food Inspection Agency, which regulates and enforces these policies. The work of both agencies follows a novelty-based system which differs from all other global regulatory regimes. This approach is created to be flexible and anticipatory to better accommodate the development of new techniques by regulating all plants with novel traits on a case-by-case basis.

As in the other study countries, knowledge about gene editing among Canadian consumers is very low (Williams et al., 2021). Many Canadians also believe gene editing is the same as GMOs (Busch et al., 2022). Research also shows that negative consumer attitudes toward GMOs stem from perceptions that biotechnology is not being applied to meet consumer needs and a lack of confidence in the country's food safety regulations (Vasquez, 2022).

4. Methods

We conducted a quantitative content analysis of newspaper articles published on GEAF in our five case study countries between 2015 and the end of 2021 (the year in which data analysis began), focusing on the sociotechnical imaginaries present, the news sources (actors) cited, and the framing of regulatory issues. 2015 was chosen as the start date for sampling as this was when a major gene editing tool, CRISPR/Cas9, began to be used for agricultural applications and received relevant media coverage. Negligible coverage was given to the topic in any of the newspapers we sampled prior to this date.

Newspaper selection

We sampled the two national newspapers with highest circulation that represent both ends of the political spectrum within each country, from business-oriented and conservative, to leftist and more liberal leaning. In Canada, we expanded our criteria to include an additional newspaper because the volume of coverage on GEAF in the two national newspapers that met these criteria was insufficient.

Sampling and coding

The online databases Factiva and Nexis Uni were used to collect articles about agricultural gene editing from all sections of the selected newspapers, including news, editorials, op-eds, and letters to the editor. The search terms "'gene edit*' and 'agricultur*,'" "'CRISPR' and 'agricultur*,'" "'gene edit*' and 'food,'" and "'CRISPR' and 'food'" (and Japanese and Dutch equivalents) were used to search all article text in the databases. Articles were manually screened and excluded if they were duplicates, less than 100 words long, or if they did not mention gene editing in the context of food and agriculture. The final sample included 180 articles.

The sampled articles were coded using an abductive content analysis approach, an iterative process involving a combination of inductive and deductive reasoning (Timmermans and Tavory, 2012) to systematically categorize features of textual data (Krippendorff, 2018). We draw from both qualitative and quantitative traditions in our analytical approach, combining a priori delineation of coding categories with iterative identification of emergent themes in the data to collect actor-level data on expressed sociotechnical imaginaries and recommendations for regulation. We began developing our coding scheme by compiling a list of forward-looking assumptions, visions and values of GEAF that had been identified in previous studies (i.e. Bain et al., 2020; Helliwell et al., 2017; Yamaguchi, 2020), creating an initial typology of imaginaries which have been expressed in discursive spheres beyond the media. After a careful preliminary read-through of the collected articles, we empirically expanded the codebook to include imaginaries that we saw appearing in the media but that had not been explicitly identified by previous studies; this part of the process was especially relevant for countries in which formal research on visions for gene editing is lacking, such as New Zealand. This abductive approach allowed us to efficiently analyze a large volume of text and directly compare the amount of "airtime" given to various imaginaries in different countries' media while deepening our conceptual understanding of how this issue is being portrayed.

For each article analyzed, we identified all segments where a specific actor (named person, company, organization, agency, or journalist) expressed imaginaries related to GEAF. Journalists were considered relevant actors if they expressed imaginaries independent from those held by other sources cited by the journalist in the same article, which was common in opinion pieces and editorials. For example, if the author of an article made a statement about a particular risk or benefit of gene editing without citing a specific source, we attributed the imaginary to the journalist. Quoted individuals who did not express a specific imaginary were not considered to be relevant actors for the purpose of this analysis. Using these criteria, we identified 517 total coding segments across the 180 articles.

For each actor who appeared in an article, their name, institutional affiliation, and expressed imaginaries were recorded. In the case that a single actor expressed more than one imaginary, which commonly occurred when one person was quoted multiple times throughout an article, we assigned multiple imaginary codes to their affiliated segment. We also noted if actors mentioned or expressed a particular stance on the regulation of GEAF. Actor-level data were later aggregated by article to facilitate additional analyses (imaginaries from different actors cited within the same article were grouped together to obtain a measure of what percentage of articles in each country mentioned a specific imaginary).

Three rounds of test coding and coder training were conducted to ensure strong intercoder reliability among a four-member coding team. After each round, coders met to discuss results and any issues experienced with the research instrument. The codebook was refined based on these discussions. The final intercoder reliability test used a 30-article subset of the U.S. sample, in which the four test coders segmented each article into relevant actor statements and then assigned relevant imaginary codes to each identified segment. The S-Lotus reliability coefficient was used to assess both the reliability of actor identification and the level of agreement among coders for each imaginary and regulatory frame code at the actor and article levels (Fretwurst, 2015) using IBM's SPSS program (IaKom, 2024). The intercoder reliability coefficient Lotus, and its standardized version "S-Lotus," were used because they overcome some issues other intercoder reliability coefficients have, such as not positively factoring identical coding of incorrect values into the overall reliability measure (Hopmann et al., 2017; Kristiansen, 2017). Lotus has been used in many studies (e.g. Bhatti et al., 2022; Blassnig et al., 2019; Brüggemann and Engesser, 2017; Humprecht and Kessler, 2024; Kleut and Milojevic, 2021; Painter et al., 2018; Wonnenberger et al., 2020) given its simplicity in both use and interpretation. The coefficient is calculated based on the value that most coders have coded (Fretwurst, 2015). The S-Lotus values for all variables in the codebook were above 0.70, and the S-Lotus value for the entire codebook was 0.92, which indicates strong agreement between coders. This pretest established the reliability of the coding instrument, which was then utilized by other trained coders to collect data from articles in other countries. Given the small sample sizes, uncertainties and specificities per country were then discussed with the entire research team if clarification was necessary.

5. Results & discussion

Our results demonstrate the major similarities and differences in the sociotechnical imaginaries presented on gene editing and its role in the food system across our five case study countries. Below, we (1) describe trends in media attention to GEAF in each country; (2) compare prevalent

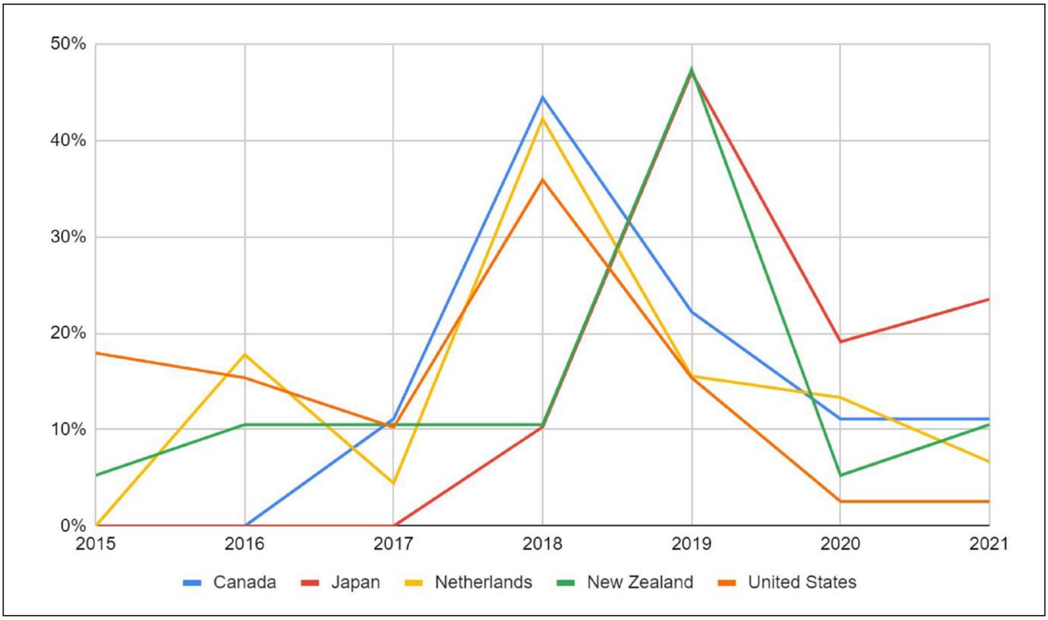

Figure 1. Percentage of total articles published on GEAF in each country, 2015-2021 (n = 9 (Canada); 68 (Japan); 45 (Netherlands); 19 (New Zealand); and 39 (United States).)
Note. See online version for color figure.

dominant and counter imaginaries within and between countries; (3) analyze which actor types are most frequently referenced; and (4) qualitatively describe how different nations' media report on regulatory issues related to GEAF.

Low media interest

Although GEAF is a relatively new, scientifically groundbreaking, and potentially socially controversial technology, the topic received only a small volume of media coverage in all our case study countries during the 6 years studied, especially in comparison to the significantly higher number of articles published on GMOs in the late 1990s and early 2000s in similar newspapers (Hibino and Nagata, 2006; Marks et al., 2003). However, considerable variability in coverage exists between countries; while only 9 articles on GEAF were published in the sampled Canadian newspapers, 68 were published in the Japanese newspapers. News attention to GEAF was moderate in New Zealand, the Netherlands, and the United States, with 19, 45, and 39 articles published in each country, respectively.

Similar to other biotechnology-related issues, media attention to GEAF appears to be primarily episodic and event-driven (McCluskey et al., 2016). For example, Japan, the country in which gene-edited varieties of tomatoes, sea bream, and pufferfish have been released, has the highest volume of coverage of the topic. Given this trend, we can expect that the news attention to GEAF will increase as products are released in the future.

Increased media attention to GEAF also appears to correlate with key regulatory decisions in each country, with the most articles published between 2018 and 2019 (Figure 1). The 2018 peaks

Table 1. Newspapers sampled in each country.

Country	Newspaper	Political orientation
US	The New York Times	Left
US	The Wall Street Journal	Right
CA	Toronto Star	Center-left
CA	National Post	Center-right
CA	Globe and Mail	Center-left
NZ	The Dominion Post	Center
NZ	The New Zealand Herald	Right
NL	de Volkskrant	Center-left
NL	NRC	Left
JP	Yomiuri Shinbun	Right
JP	Asahi Shinbun	Center

correspond to the USDA announcement which exempts non-transgenic gene-edited crops from regulatory review and the ECJ ruling that classified gene editing as a technique of genetic modification. Similarly, the 2019 peak for New Zealand appears to correspond with the Australian government's decision to not regulate certain gene-edited products, a ruling which spurred New Zealand's proponents of GEAF to argue that deregulation was necessary for the country's agricultural sector to remain economically competitive.

Prevalent imaginaries in each country

All case study countries' media more frequently featured dominant imaginaries than counter imaginaries, with the most common overall being that gene editing will revolutionize agricultural innovation (Table 3). This finding supports recent research which shows that GEAF is being covered more positively than GMOs in news media (Dahlstrom et al., 2022). By making dominant imaginaries more explicit and communicating them to the public, the media helps embed and stabilize these already influential discourses.

However, some dominant imaginaries appeared less frequently than expected. For example, in contrast with the findings of Bain et al. (2020), the imaginary that gene editing could help ensure global food security appears infrequently in all countries' news media. This suggests that journalists attribute a low news value to this narrative, as food insecurity may be less relevant for consumers in developed countries (Harcup and O'Neill, 2017), or that the actors with a voice in media coverage do not promote this perspective. Another imaginary which appears infrequently is that gene editing will democratize agricultural biotechnology by being accessible to a wider range of actors, such as small companies and public breeders, which was also observed in previous research (Bain et al., 2020). One potential explanation for this discrepancy is that foregrounding this imaginary in the media would create an opportunity for activists to respond with critiques of how corporate interests shape the current food system and visions of what it should look like in the future. By emphasizing GEAF's potential benefits for innovation, consumers and the environment rather than its possible implications for equity, actors who construct and communicate dominant imaginaries may be attempting to limit critical voices to focusing on what they perceive as technical risks of the technology rather than more systemic critiques of how it might perpetuate existing power dynamics in the food system.

Table 2. Dominant and counter imaginaries with coding examples.

Dominant Imaginaries

Imaginary	Description/coding rationale	Example from media
Different & better than GMO	The actor expresses the view that gene editing differs from transgenic technology, describes it as an improvement over GM tools, and/or states that existing regulation of GMOs is not applicable to products of gene editing because of fundamental differences between the tools. The actor may also describe the products of gene editing as being equivalent to those that could be achieved through conventional breeding.	"Let's be clear about why we need a new conversation, not a re-run of the 'GM Debate'. Firstly, the technology is very different. Gene editing offers game-changing capability well beyond earlier GM tools. It allows breeders to make precisely targeted changes to a plant without introducing any foreign DNA. Those changes are the same as those found in nature. You can't 'test' for gene editing because it leaves no trace." (Hughes, 2019).
Benefits for consumers	The actor describes ways in which gene editing can be used to develop traits that will directly benefit consumers (as opposed to developers or farmers), including but not limited to lower costs, improved flavor, eliminating allergens, higher nutritional value, and reduced personal food waste. The actor may also mention that developing consumer-oriented traits is important for ensuring public acceptance of the technology.	"Professor Taku Yamamoto of Hiroshima University, President of the Japanese Society for Genome Editing, emphasized the possibility of obtaining food products that meet consumer needs, such as those with low allergies, saying, 'It is important for researchers to come forward and explain the process. We would like to explain as much as possible to deepen the public's understanding'," (Miura, 2019).
Democratization of agricultural biotechnology	The actor describes gene editing as an accessible technology and/or claims that commercializing products will cost less if they are deregulated, which will allow smaller companies and university-based breeders to utilize the tool. The actor may also mention that this increased access will lead to a wider diversity of crops being improved.	"Freedom from oversight could also open opportunities for smaller companies and university breeders and for the modification of less common crops. Until now, in part because of the costs associated with regulation, crop biotechnology has been dominated by Monsanto and a handful of other big companies working mainly on widely grown crops like corn and soybeans." (Pollack, 2015).
Ensuring global food security	The actor describes gene editing as a tool that can help feed a growing world population by increasing crop yields and/or improving crop resilience to pressures such as drought or disease.	"Persuading consumers to support gene-edited crops will require engaging them 'at the very local level,' Mr. Collins said. The agriculture industry, he said, must communicate to people how a variety of corn, with its DNA edited to better resist drought, can help feed a global population projected to rise to nearly 10 billion by 2050, for instance." (Bunge, 2017).

(Continued)

Table 2. (Continued)

Dominant Imaginaries

Imaginary	Description/coding rationale	Example from media
Benefits for sustainability	The actor describes ways in which gene editing could be used to improve the sustainability of agriculture. Common examples include reducing pesticide use, improving carbon sequestration capacity, decreasing water needs, and lessening post-harvest food waste.	"For the time being, the ban applies to all plants—including conventional crops—in the European Union, but there is an increased awareness that we cut out an important tool for sustainable agriculture. With these techniques, CRISPR/Cas among them, we can create plants with better nutritional value and yield. Amongst others because they contain more healthy nutrients and are more resistant against diseases and plagues. This would be no luxury in light of climate change." (van Kasteren, 2021).
Safe for humans and the environment	The actor emphasizes the safety of the process and/or products of gene editing for either human or ecosystem health. They may do so by mentioning the technology's precision, describing the rigorous pre-market testing of products, referring to a lack of negative impacts of previous transgenic crops, or expressing the position that gene editing is no riskier than other long-used conventional breeding methods.	"The British Royal Society of Medicine and the European Food Safety Authority (EFSA) conclude that genetically manipulated plants do not pose any increased health risks. The WHO also stated no effects on human health due to the consumption of genetically modified food." (de Groot, 2018).
Revolutionizing agricultural innovation	The actor emphasizes gene editing's potential to quickly provide unique benefits for agriculture that could not otherwise be realized. The actor may also state that a permissive national and/or global regulatory landscape is required to foster innovation.	Memorial University geneticist Jessica Esseltime cited the rapid speed and inexpensive cost of gene editing compared to traditional genetic modification, saying "now, I can do a CRISPR on Friday, and on Monday, I will have a genetically modified organism in my hands. And it will cost me less than $100." (Jackson, 2020).
Important for national economy	The actor describes how gene editing can bolster a particular national economy by improving specific crops and/or making the agricultural sector more competitive overall. The actor may also mention that failure to adopt gene editing technology could have negative economic consequences.	"Without the ability to use gene editing, New Zealand will be prevented from growing food that is better for the environment, and our industries will fall behind our trading partner and competitors." (The New Zealand Herald, 2019).

(Continued)

Table 2. (Continued)

Counter Imaginaries

Imaginary	Description/coding rationale	Example from media
Same as GMOs	The actor expresses the view that gene editing is the same as genetic modification. They may also use phrases such as "new GMOs" or "GMO 2.0" to describe gene editing. The actor may advocate for or speak in support of a regulatory framework that views the technologies as equivalent.	"Environmentalists, anti-GM groups and farmers have said allowing gene editing would usher in a new era of 'GMO 2.0' via the backdoor." (Chee, 2023).
Pose risks for humans and environment	The actor expresses concerns that gene editing could pose safety risks for humans and/or the environment. The actor may mention a lack of sufficient research/data on product safety and/or the potential for off-target effects which lead to unintended consequences. The actor may also mention that a stringent regulatory framework, particularly one which applies the precautionary principle, is necessary to minimize public risk.	"Tetsuya Ishii, a professor of bioethics at Hokkaido University, pointed out that breaking a gene may cause unexpected changes or cuts in unexpected places, resulting in the formation of allergic substances. He argues, 'It is important not to simply declare that a product is safe, but to carefully explain the risks to the public while showing the degree of risk through component analysis and other means.'" (Asahi Shinbun, 2018).
Encourage corporate control	The actor expresses concerns that widespread use of gene editing will exacerbate issues of corporate control in agriculture. Issues mentioned may include the negative impacts of restrictive intellectual property rights regimes, increasing farmers' dependence on technology, trade-offs between investing in biotechnology and alternative approaches, and the relationship between economic and regulatory control.	"Today, land-grant breeders are an endangered species. (Many have been replaced by plant scientists studying the genome, supporting the next generation of genetic tinkering like Crispr – often at the expense of classical plant breeding research.) Hundreds of programs have been whittled down to single digits for each crop. Onions are down to three land-grant breeders. Sweet corn has two. Carrots have just one: Irwin Goldman at the University of Wisconsin, Madison." (Barber, 2019).

(Continued)

Table 2. (Continued)

Counter Imaginaries

Imaginary	Description/coding rationale	Example from media
Take away consumers' right to choose	The actor expresses concerns that having unlabeled gene-edited products on the market will infringe on consumers' rights to make personal risk-benefit decisions when purchasing food. The actor may advocate for greater transparency in labeling and/or a greater consideration of consumers' needs and wants in developing products and regulatory frameworks.	"Nutiva's Mr. Roulac helped set up a website called GMOinside.org to campaign against genetically engineered crops. The website describes gene editing as "genetic engineering 2.0" and warns that 'if left unchecked it will sneak its way onto every grocery store shelf.'" (Bunge and Marcus, 2018).
Not the solution to issues in the food system	The actor emphasizes that technological approaches like gene editing cannot address systemic issues in the food system and may in fact create more problems than they solve. The actor may also bring up alternative approaches, such as organic agriculture, agroecology, or traditional breeding, which they argue can accomplish the same things that proponents claim gene editing can but with less risk and required resources.	"Hughes also argued there were risks to New Zealand's organics sector and national agricultural reputation that needed to be considered. 'There are emissions reduction practices available right now without needing hypothetical, future GE-based technologies,' he said." (Morton, 2019).
Harmful for national economy	The actor expresses concerns that adopting gene editing in agriculture will negatively impact a particular nation's economy by decreasing the desirability of its exports in markets which are unfavorable toward genetically modified crops.	"If we are talking about public interest science, we ought to be debating the alternative commercial arguments around being organic, sustainable, ethical, environmentally clean and green—which is really what the cornerstones for our market exports are." (The Dominion Post, 2019).

Table 3. Percentage of newspaper articles that include each imaginary, sorted by average prevalence across all countries (n = 9 (Canada); 68 (Japan); 45 (Netherlands); 19 (New Zealand); 39 (United States)).

Dominant Imaginaries

Variable	CA	JP	NL	NZ	US	Avg.
Revolutionizing agricultural innovation	**67%**	12%	**47%**	32%	49%	41%
Different & better than GMO	44%	11%	36%	32%	**56%**	36%
Benefits for sustainability	11%	3%	**47%**	**74%**	18%	30%
Benefits for consumers	56%	12%	36%	11%	23%	27%
Ensuring global food security	22%	6%	31%	11%	15%	17%
Safe for humans and environment	0%	**27%**	24%	16%	8%	15%
Important for national economy	0%	7%	29%	21%	3%	12%
Democratization of biotechnology	11%	2%	22%	0%	8%	9%l

Counter Imaginaries

Variable	CA	JP	NL	NZ	US	Avg.
Pose risks for humans and environment	**22%**	**21%**	**29%**	11%	**31%**	23%
Same as GMOs	11%	2%	**29%**	0%	13%	11%
Take away consumers' right to choose	0%	19%	4%	0%	3%	5%
Encourage corporate control	0%	1%	9%	0%	8%	4%
Not the solution to issues in the food system	0%	0%	4%	11%	3%	4%
Harmful for national economy	0%	0%	0%	11%	0%	2%

Bold value represents the highest percentage for each country.

Some critical imaginaries received more coverage than others, which may also influence public perception of possible alternatives to GEAF and the actors that support them. The most common counter-imaginary cited in the articles by far related to gene editing's health and environmental risks. The counter-imaginary "gene-edited foods are the same as GMOs" also appears frequently in articles from Canada, the Netherlands, and the United States, illustrating efforts by critics to connect GEAF to a historically controversial topic. In contrast, very few articles in our sample featured systemic critiques, such as gene editing encouraging further corporate control of food or technology not providing adequate solutions to pressing food system issues. Infringement on consumer rights was also a minimally represented theme in all countries other than Japan. Given the central role that scientism has historically played in policymaking on biotechnology in Western nations, the emphasis on these technical issues reflects the continued tendency for social movement actors to justify their agendas by narrowly focusing on physical hazards which can be measured using objective scientific principles (Kinchy, 2012).

The limited coverage of more far-reaching criticisms also influences critics' (in)ability to destabilize dominant imaginaries. Kinchy (2012) argues that social movements are most successful in influencing decision-making when they challenge the overreliance on expert knowledge of quantifiable risks to the exclusion of social, cultural, and ethical dimensions. Recent research on public perception of GEAF suggests that some consumers' opposition to agricultural biotechnology is rooted in broader political and economic critiques of the food system, rather than solely concerns about food safety or environmental impacts (Nawaz and Satterfield, 2022). However, the results of our content analysis reveal that, overall, critical actors in the mass media are *not* expanding the debate about GEAF to include broader issues, instead continuing to present these issues in predominantly narrow technical terms. This may also limit participation of a greater diversity of actors in decision-making about GEAF's development, regulation, and application (Kinchy, 2012; Nisbet and Huge, 2006).

Despite overarching similarities, results show that these imaginaries have not traveled and expanded in space and time uniformly, as the prevalence of each imaginary varied considerably between countries, reflecting unique cultural contexts and regulatory paradigms. For example, the especially strong focus in American media coverage on differentiating GEAF from GMO suggests that proponents of gene editing in this country expect that public trust and acceptance will be hindered if the two technologies are conflated. Given the observed strong influence of industry actors on the media narrative in the United States, this emphasis is likely a response to the long history of strong anti-GMO sentiment among some segments of the public, for whom criticisms often revolved around the "unnaturalness" of transgenic technologies which have already been utilized for decades (Kinchy, 2012).

Another important difference between countries is that newspaper articles in Japan, New Zealand, and the Netherlands feature the dominant imaginary that "gene-edited foods are safe for humans and the environment" frequently, while few articles in the United States and Canada do. This varying degree to which proponents mobilize safety-oriented discourses could be driven by each nations' history of biotechnology use. In countries where GM crops have been grown for decades (United States and Canada), not directly emphasizing safety of these new varieties may marginalize opponents by portraying them as ignoring scientific consensus that gene-edited foods are functionally the same as crops developed using traditional breeding methods. In contrast, in countries where civic concerns about safety have successfully restricted GMO development and plantings in the past, convincing the public of the safety of gene-edited crops remains an important priority for actors who wish to see the technology succeed. For example, Japan's precautionary regulatory approach and higher levels of consumer skepticism is reflected in the focus on safety in the media, by both proponents and opponents.

Finally, media coverage of GEAF in New Zealand and the Netherlands also focuses more strongly on both dominant and counter imaginaries about GEAF's implications for sustainability and the economy, reflecting both countries' history of economic reliance on high-quality, sustainably-grown agricultural exports.

Types of actors and associated imaginaries

Different types of actors dominate media coverage of GEAF in each country (Figure 2), reflecting differences in discursive power held by certain groups in particular cultural contexts. Academic scientists are the most commonly cited actors overall. American and Canadian media coverage are also dominated by representatives of private biotechnology companies, evidence that these actors continue to have a strong influence on originating sociotechnical imaginaries and national public narratives around GEAF. These two actor groups tended to express mostly dominant imaginaries, especially those related to the technology's potential impacts on agricultural innovation, sustainability, and consumer benefits. Journalists (in the United States, New Zealand, and Netherlands) also overwhelmingly favor dominant imaginaries, with only a few taking critical stances on GEAF. In contrast, consumer advocacy groups, environmental non-profits, and NGOs, who express primarily counter imaginaries, are rarely cited across all countries.

Other actor groups held mixed positions, varying either between or within each country's media coverage. For example, representatives of the food and agriculture industries express a wide range of both dominant and counter imaginaries, especially in the Netherlands, where they are a relatively prominent actor type. This reflects the diverse identities of actors who fall into this group, ranging from employees of natural food companies to spokespeople for commodity associations.

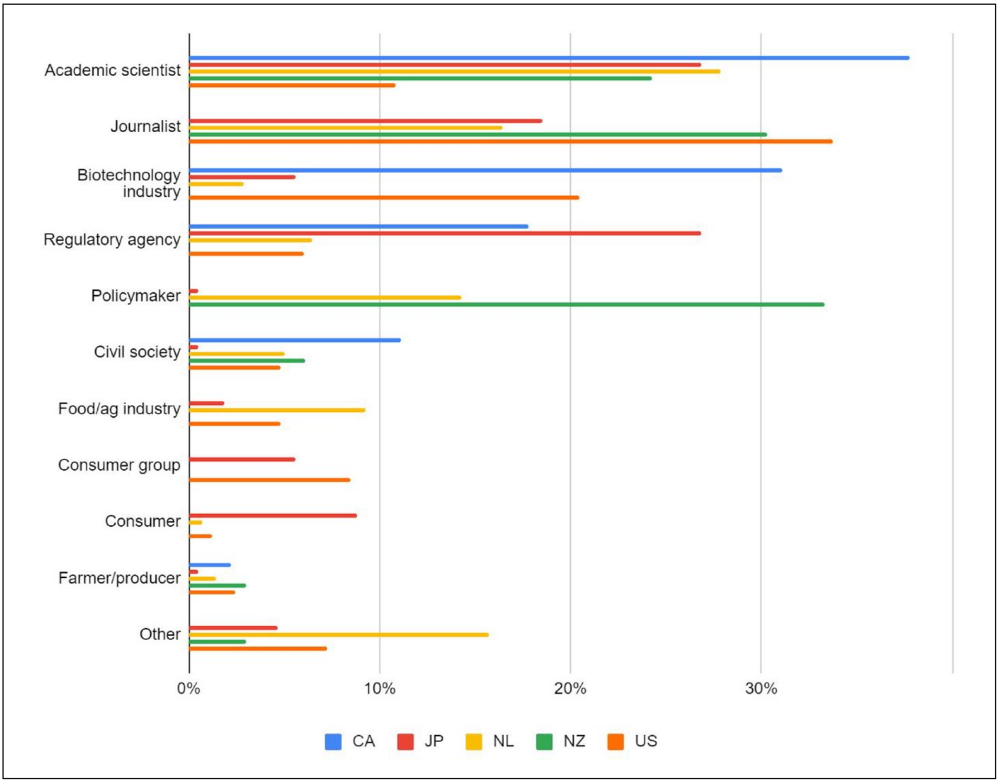

Figure 2. Percentage of total actors in each category in each country's newspaper articles (n = 45 (Canada); 216 (Japan); 140 (Netherlands); 33 (New Zealand); 83 (United States)).
Note. See online version for color figure.

In the two countries in which they were a prominent actor group, policymakers also expressed both dominant and counter imaginaries, although the specific imaginaries highlighted differed between the Netherlands and New Zealand. In the Netherlands, policymakers often referred to gene editing's relationship to GMOs, either affirming or challenging the idea that these new tools were different from previous transgenic approaches. In contrast, New Zealand's policymakers in favor of the technology tended to emphasize gene editing's potential benefits for sustainability, whereas those opposed to it highlighted possible harms for the national economy.

Regulatory agencies also advanced different imaginaries in different countries. In the Netherlands, regulators expressed a mix of dominant and counter imaginaries about gene editing's safety, focusing on whether or not the tool poses substantial risks for human health or the environment. However, in the United States and Canada, regulators mostly express dominant imaginaries; they rarely mention safety, instead focusing on gene editing's differences from GMOs and the potential consumer benefits that the tool could offer. In Japan, where regulators were cited most often, content from these agencies is also homogeneously positive, although, like their Dutch counterparts, these actors also discuss safety issues.

Across all countries, when actors expressed counter imaginaries, they were often followed in the text by actors expressing contradictory dominant imaginaries, which may effectively undermine these critiques. For example, policymakers and food and agricultural industry representatives quoted in Dutch media would refer to the ECJ judgment and subsequently comment that the decision was unjustified due to the technology's safety or similarity to conventional breeding. Similarly, in United States articles, while representatives of civil society groups were occasionally cited expressing concerns about GEAF, journalists typically followed these quotes with responses from proponents of GEAF dismissing these claims and advancing dominant imaginaries. In contrast, in most instances where actors expressed dominant imaginaries, no actors expressing counter imaginaries were simultaneously included.

These results show that media representation is uneven: the powerful actors who express dominant imaginaries receive significantly more airtime in media coverage of gene-edited foods in all case study countries. In other words, not only do already dominant narratives appear in a greater number of articles, but a greater number of voices in support of these narratives appear within each article. This finding is consistent with previous research on media coverage of genetic engineering which has found that news sources that represent government interests and express positive views are more frequently cited, due to both journalistic routines and the perceived credibility of these actors (Ashwell, 2011; Kohring and Görke, 2000; Nisbet and Lewenstein, 2002). The prominence of these voices overshadows other perspectives, particularly those held by individuals or groups who wish to challenge the status quo of industrial agriculture, such as critical scientists or environmental advocates and activists. This lack of other actor types limits the broader conversation around GEAF and seems to undermine the democratization narrative being cultivated by proponents of the technology. By cultivating the perception of consensus, the media also undermines the ability of dissident actors to mobilize public opposition.

Regulatory concerns

Regulation is a consistently prevalent topic in media coverage of GEAF. Regulatory issues also appear to be a driving factor behind media attention toward GEAF; as mentioned earlier, the volume of coverage increased following key policy decisions related to gene editing, which had implications for each case study country's collective visions of the technology. This finding demonstrates that media attention to issues such as plant biotechnology continues to fluctuate based on key debates and decisions in policy making arenas (Nisbet and Huge, 2006).

Across all countries' media, actors who expressed dominant imaginaries often advocated for less stringent regulation, arguing that a streamlined approach was necessary for realizing GEAF's benefits. For example, academic scientists and biotechnology company representatives often emphasized that gene editing's precision, safety, and similarity to conventional breeding approaches meant that costly and time-consuming regulatory processes were unnecessary and would hinder innovation to the detriment of consumers and the environment. Consumer and environmental groups, in contrast, tended to advocate for stricter regulation and governance, including transparent labeling of any products that contain gene-edited ingredients.

Two differences in media reporting on regulation in the five case study countries are notable. First, the American and Canadian media give proportionally less attention to the topic of regulation than the Netherlands, New Zealand, and Japan. Second, actors in different countries discuss regulation with varying degrees of specificity. When actors in the U.S. media mention regulation, the majority do not explicitly advocate for a particular approach, instead simply describing the current regulatory status of the technology without an associated value judgment. In contrast, actors in New Zealand and the Netherlands more often made specific recommendations about what regulation of GEAF should be. Policymakers were quoted on this topic especially frequently in these two countries; they advocated for a mix of regulatory approaches, often speaking either in defense of or against their nations' existing frameworks. This may reflect the ongoing contestation around how gene-edited foods should be defined and regulated in New Zealand and the EU, as some quoted policymakers emphasized that the decision to regulate GEAF as GM could still be revisited by members of Parliament or the ECJ. In contrast, the more generic mentions of regulation by United States actors, combined with fewer articles mentioning regulation overall, suggest the USDA decision to deregulate non-transgenic gene-edited crops is perceived as more final.

However, few advocates of deregulation in any country justified their position using the imaginary that GEAF will democratize biotechnology, a prominent argument among actors who advocate for deregulation in discursive spheres beyond the mass media (Bain et al., 2020). As discussed above, one potential explanation for this discrepancy could be that actors in favor of deregulation are intentionally choosing not to highlight the ways that gene editing could restructure power in the biotechnology sector, instead emphasizing consumer and environmental benefits which resonate more strongly with the newspapers' readers.

Sociotechnical imaginaries can either legitimize or challenge existing governance structures for technologies like gene editing by juxtaposing the benefits of certain regulatory paradigms for achieving ideal futures against the risks or hazards of adopting alternative approaches (Jasanoff and Kim, 2009). The relative dominance of proponents' voices in newspaper articles published in all case study countries suggests that the media is contributing to the stabilization of the current regulatory approach in the United States, Canada, and Japan while challenging it in New Zealand and the Netherlands.

6. Conclusion

The aim of this study was to conduct a comparative analysis of sociotechnical imaginaries of GEAF and actors expressing these imaginaries in mass media across countries with different regulatory and cultural contexts. Despite variations that reflect each country's sociocultural and regulatory landscape, five overarching conclusions emerge.

First, our results underscore that the media in each of our five case study countries are contributing to the embedding of predominantly positive portrayals of the technology's future. Gene editing's potential for revolutionizing agricultural innovation is consistently emphasized, while issues such as food security and the democratization of biotechnology are rarely mentioned.

Second, media coverage of GEAF also primarily cites already influential actors, such as scientists, industry, and government representatives, elevating these voices over those of producers, consumers, and civil society groups. These influential actors feed into the life-cycles of sociotechnical imaginaries. As places of origin, they are also important holders of assumptions, values, and visionary ideas about the GEAF, which they further embed into collectively held imaginaries through media. The overwhelmingly one-sided media coverage is reminiscent of the early approach to reporting on GMOs in many Western countries' media (Nisbet and Lewenstein, 2002). By highlighting these topics and actors, the media is portraying gene editing as a desirable and necessary component of future agrifood systems while narrowing the scope of issues under consideration in its development and application.

Third, variations exist in which imaginaries are most mobilized and by which actors across different countries' media coverage of GEAF. For example, in countries where civil society concerns about safety and environmental risks have historically restricted the development of GM crops, such as Japan, New Zealand, and the Netherlands, the dominant imaginary that "gene-edited foods are safe for humans and the environment" appears more frequently, reflecting an active effort by proponents to positively shape consumer attitudes.

Fourth, a clear link also exists between the technology's regulatory status in a given region and the imaginaries mobilized in the media. In the countries where GEAF regulation is currently contested, New Zealand and the Netherlands, both the dominant and counter imaginaries highlighted tend to promote issues of broader appeal to the public, like agricultural sustainability and the importance of agriculture to the national economy. These topics are infrequently mentioned in the United States, Canada, and Japan, where regulation of GEAF is less publicly controversial; media in this latter group of countries instead tend to portray gene editing's potential for revolutionizing the future of agriculture, and therefore, differentiating GEAF and GMO is key. These variations in imaginaries may shape national agricultural transitions and impact what role gene editing may play in achieving envisioned agrifood futures, for example, by shaping public perceptions around what types of products can or should be developed and who should be involved in decision-making (Kjeldaas et al., 2023).

Fifth, in the limited instances in which the media highlight minority perspectives or critical stances on GEAF, they typically emphasize only counter imaginaries that challenge the technology's safety for human health or the environment. Portraying GEAF's critics as primarily being concerned with technical risks does little to challenge the dominant narrative that the technology is a necessary component of future agrifood systems, and instead may perpetuate the idea that adequate regulation will solve all potential issues. This could also promote an emphasis on technical issues in developing regulatory frameworks in countries where the status of GEAF has yet to be determined, while broader social and ethical issues such as control over genetic resources, or whether the technology *should* be used, remain unaddressed.

Because sociotechnical imaginaries frame the boundaries of what is perceived as necessary and possible, media coverage which embeds some imaginaries over others may shape collective public understandings of agrifood systems and potential futures. The consistent emphasis on the benefits of innovation, for example, normalizes a technological approach to addressing narrowly defined environmental challenges. This technological optimism also reflects a phenomenon at work in the media coverage of other biotechnologies and the influence of powerful actors on what is covered. Smith (2015), for example, shows how the biotechnology company Syngenta had a dilemma over "sharing [with the public] information and technologies", where "'doing right' conflicted with the potential harm of negative publicity" (p. 272) during the decisions and negotiations over ownership and control of golden rice. Smith (2015) concludes that a central question appears to be who has the power to decide upon those responsibilities when powerful actors are withholding information and mobilizing imaginaries in their favor.

Similarly, opponents' limited problem definitions which emphasize technical risks may further promote simplistic solutions to complex issues while also restricting who is able to participate in decision-making on GEAF's development and governance (Kjeldaas et al., 2023). The embedding of these specific imaginaries could contribute to keeping approaches that advocate for systemic changes out of the public and political discourse, thus perpetuating the status quo by impeding alternatives from being invested in and therefore realized (Smallman, 2020).

In sum, we argue that observed differences among our study countries result from the media's role in both reflecting and publicly performing a country's historically situated sociotechnical imaginaries while attempting to de/stabilize certain narratives around GMOs. This study contributes important new insights into how expectations related to gene-edited foods are communicated to the public in countries with different regulatory contexts and historical relationships with agricultural biotechnology. By focusing on sociotechnical imaginaries of GEAF, and the actors advancing them in the media in several countries, we show how the technology is situated and reflects the values of proponents in each country, contributing to the emergent field of agrifood technoscience scholarship (Gugganig et al., 2023). We call for future research to examine media coverage of this issue in a broader range of countries, especially in the Global South, where historical and structural dynamics of agrifood systems differ greatly from the countries studied here.

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Supplemental material

Supplemental material for this article is available online.

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