Food Ethics (2024) 9:7
https://doi.org/10.1007/s41055-024-00143-z

RESEARCH ARTICLE

"Frequently Asked Questions" About Genetic Engineering in Farm Animals: A Frame Analysis

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Accepted: 16 January 2024

Abstract
Calls for public engagement on emerging agricultural technologies, including genetic engineering of farm animals, have resulted in the development of information that people can interact and engage with online, including "Frequently Asked Questions" (FAQs) developed by organizations seeking to inform or influence the debate. We conducted a frame analysis of FAQs webpages about genetic engineering of farm animals developed by different organizations to describe how questions and answers are presented. We categorized FAQs as having a regulatory frame (emphasizing or challenging the adequacy of regulations), an efficiency frame (emphasizing precision and benefits), a risks and uncertainty frame (emphasizing unknown outcomes), an animal welfare frame (emphasizing benefits for animals) or an animal dignity frame (considering the inherent value of animals). Animals were often featured as the object of regulations in FAQs, and questions about animals were linked to animal welfare regulations. The public were represented using a variety of terms (public, consumer) and pronouns (I, we). Some FAQs described differences between technology terms (gene editing, genetic modification) and categorized technologies as either well-established or novel. This framing of the technology may not respond to actual public concerns on the topic. Organizations seeking to use FAQs as a public engagement tool might consider including multiple viewpoints and actual questions people have about genetic engineering.

Keywords Qualitative · Public engagement · Animal agriculture · Genetic modification · Gene editing

Introduction

Genetic engineering (i.e., biotechnology altering the genetic information of an organism) has generated a range of applications (Tait-Burkard et al. 2018) as well as ethical questions about the use of this technology (de Graeff et al. 2019). Newer methods, such as clustered regularly interspaced palindromic repeats (CRISPR) and the CRISPR-associated protein 9 (Cas9), have now been applied to farm animals to achieve a variety of goals (e.g., to increase disease resistance and heat tolerance; de Graeff et al. 2019). This surge in

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applications has led to renewed questions about the ethics (e.g., Kramer and Meijboom 2021) and public acceptance of these technologies (de Graeff et al. 2019).

Calls to engage the public in discussions about novel technologies including genetic engineering (also referred to as genome or gene editing, genetic modification; collectively referred to in this paper as genetic engineering or GE) have long existed (Rowe and Frewer 2000, 2005). Public engagement goals vary (PytlikZillig and Tomkins 2011) but often aim to increase public trust (Frewer et al. 2003; Siegrist 2000). Some goals focus on educating people who are assumed to lack knowledge about the technology, an approach known as the public or information deficit model (Christiano and Neimand 2017; Wynne 2006). Other attempts aim to counteract certain public attitudes and sway perceptions (Rempel et al. 2019; Supran and Oreskes 2021). As well, the way the "public" is conceived varies (Meyer 2020), with scholars applying terms that they link back to society, such as citizens, consumers, public and publics, making it difficult to summarize public views (Davies et al. 2021; Rempel et al. 2018). Thus, it may be useful to recognize the public as made up of dynamic, overlapping groups (Rempel et al. 2019).

One approach to analyzing public engagement goals, specifically what and how information is presented to the public, is via frame analysis. Conceptual and methodological approaches to frame analysis come from disciplines like media, communications studies and sociology (Foley et al. 2019). The terms "frame", "framing" and "framework" are used literally and metaphorically in everyday and scholarly discussions (Entman 1993; Tankard 2001). Tankard (2001) reviewed the use of metaphors to describe frames, including Goffman's (1974) presentation of "strips" (i.e., slices of everyday ongoing activity) enclosed in a "picture frame", and Gamson's (1989) relating of the term "frame" to architecture, meaning an "organizing structure" used to build something. In enclosing a "strip" or using an "organizing structure", other possible scenes are excluded, thus shaping interpretations (Entman 1993). Simply put, a frame is "a particular way an issue is presented" (Foley et al. 2019, p. 1812).

There are many forms of public engagement. Efforts to directly engage the public in discussions about GE in animals have included government initiatives (e.g., Macnaghten 2001), multi-stakeholder roundtable discussions (e.g., Pew Trust 2005) focus groups (GeneInnovate 2020) and virtual public consultations (e.g., Nuffield Council on Bioethics 2021). These efforts have generated a body of work, including reflection on the meaning of engagement (Rempel et al. 2019), effective engagement (Scheufele et al. 2021), strategies for inclusive engagement within the Responsible Innovation framework (Stilgoe et al. 2013), and the incorporation of actual public concerns into academic research (de Graeff et al. 2019).

Researchers have also investigated how technologies are framed within the public sphere where people engage and interact with information. For example, media analysis of agrobiotechnology and genetically modified food is common (e.g., Hagedorn and Allender-Hagedorn 1997; Lin 2021) and frames have also been examined in experimental surveys where participants receive information and then judge novel technologies. Experimental surveys often provide short descriptions that use an explicit framing, and test how these frames affect participant attitudes toward the technology, including potential benefits for animal welfare, the environment, worker safety, and human health (McConnachie et al. 2019; Yunes et al. 2021). Others have examined how people responded to technology terms (e.g., gene editing, genetic modification) paired with information sources like scientific articles or blogs (Bearth et al. 2022; Yang and Hobbs 2020).

More recently, work has examined how GE technologies are presented online, including differences in how information is communicated (Brossard 2019) and shared on Wikipedia

(Calabrese et al. 2019). Others have analyzed comments on social media platforms like Twitter (now called "X"; Hill et al. 2022) and Facebook (Walker and Malson 2020). Although not focused on GE, McLeod and Hobson-West (2016) reported that webpages about "institutional transparency" in animal research laboratories were framed differently depending on whether the webpage was produced by animal protection groups or the animal research community. Thus, members of the public have access to information sources that are framed differently.

Possibly because people are asking more questions about GE, but also likely because some seek to shape the debate, organizations have created lists of "Frequently Asked Questions" (FAQs). FAQs were developed in the early 1980s to avoid answering recurring questions from people when the Internet was in its infancy (Hersch 1997). Today, FAQs are common and research has examined FAQs on topics including COVID-19 vaccines (Sajjadi et al. 2021) and climate change (Connors et al. 2022). Frequently Asked Questions webpages about GE may provide insight about how organizations present information about GE to members of the public. Specifically, identifying which topics organizations include (and exclude), how they refer to the public, and how they construct answers to questions they choose to address can provide insight into how organizations frame the debate about GE in animals. We used frame analysis to analyze GE FAQs with two central study aims: (1) to describe how questions and answers about GE are framed, and (2) to describe the ways in which animals and the public are presented.

Materials and Methods

Ethics

This study did not require ethical review from the University of British Columbia Behavioral Research Ethics Board because it relied on information that is "in the public domain and the individuals to whom the information refers have no reasonable expectation of privacy" (TCPS2 2022, article 2.2, 17).

FAQs Webpage Search

This study utilized FAQs about GE in farm animals that we found online while conducting a grey literature review search using search terms like "what is gene editing in animals?" After finding several FAQs webpages, we developed a systematic search strategy. FAQs webpages can be considered a type of grey literature; i.e., reports produced by governments, institutes, industry, and non-profit organizations that are not published in academic, peer-reviewed journals and are generally intended for lay or professional (rather than academic) audiences. To develop our search, the first author consulted a librarian and followed guidance of Godin et al. (2015). Specifically, she performed a Google search to identify FAQ webpages about GE in animals, using the private browsing function and four search phrases: "frequently asked questions about gene editing in animals", "frequently asked questions about genetic modification in animals", "frequently asked questions about genetic engineering in animals", and "frequently asked questions about genome editing in animals." For each search she screened the first 50 search returns and compiled an initial list of webpages (n.b., we considered it unmanageable to review all returns; for example, the phrase "frequently asked questions about gene editing in animals" returned 33.4 million

Table 1 Search terms using the "intitle:" advanced Google search function where each question phrase was paired with each term phrase

Question phrase	Term phrase
commonly asked questions	and gene and animal and edit
frequently asked questions	and gene and animal and modify
questions and answers	and gene and animal and engineer
FAQ	and genome and animal and edit
FAQs	and genome and animal and modify
	and genome and animal and engineer

Table 2 Inclusion and exclusion criteria for Frequently Asked Questions webpages to be included in frame analysis

Inclusion criteria	Exclusion criteria
Available in English	Unavailable in English
Most current version of the FAQs	FAQs have been replaced by a more recent version
Intended for a lay audience	Intended for an expert or technical audience (e.g., heavy use of technical terms, acronyms, or jargon)
Webpage is in question-and-answer format or uses the term FAQ or CAQ (Commonly Asked Question)	Webpage is not in question-and-answer format or does not use FAQ or CAQ
Focus is on gene editing in farm animals	Focus is on gene editing in humans or wild, companion animals or animals used in research
Free	Access limited by paywall
FAQs webpage connected to an organization, agency, institute, government, or university	FAQs webpage connected to a blog, social media, media, or popular press

items). She then also performed an advanced Google search using the private browsing and "intitle" function whereby each question phrase was combined with each term phrase (Table 1). Given that our aim was to understand what people could easily access we limited our search to Google. The first author screened results (ranging from 23 to 300 returns) for each search and then developed inclusion criteria (Godin et al. 2015) through an iterative process of narrowing and defining criteria (Table 2). This process involved selecting FAQs presented in lay language (i.e., not technical, little jargon use).

After applying our inclusion criteria, we identified 60 FAQs webpages. We then eliminated 23 that focused on food and labeling and 15 that focused on plants. Of the remaining 22, we eliminated six that contained little information about animals or were broadly about biotechnology, four about gene drives, and another two about transgenic mice in research laboratories. The final dataset included 10 FAQs webpages about GE in farm animals. Table 3 lists each webpage, abbreviations used in this paper, the Uniform Resource Locator (URL; accessed May 19, 2023) and other information.

Existing Frames

We used frame analysis following Entman (1993) and analytical guidance built on Entman's approach (Foley et al. 2019; Matthes and Kohring 2008). Matthes and Kohring (2008) and Foley et al. (2019) proposed a step-by-step process using frame elements to analyze frames systematically. Frame elements include the *problem definition, moral*

Table 3 Descriptive information about Frequently Asked Questions webpages including organization name and type, abbreviation used in paper, URL (accessed May 19, 2023), terms used and additional links provided

Organization (abbreviation)	Organization type	URL	Terms used	Additional links provided
Acceligen (Acceligen)	Industry	https://www.acceligen.com/faqs/	Precision breeding and gene editing used interchangeably	UN Sustainable Development Goals, Contact Us
Biotechnology Innovation Organization (Biotechnology)	Industry	https://archive.bio.org/articles/genetically-engineered-animals-frequently-asked-questions	Genetically engineered	FDA GE animals resource; Biotechnology scientific report; AquaBounty press room; Enviropig™ website
Center for Science in the Public Interest (Center)	Consumer advocacy	https://www.cspinet.org/protecting-our-health/biotechnology/frequently-asked-questions	Genetically engineered	None
Department for Environment, Food & Rural Affairs (DEFRA)	UK government	https://consult.defra.gov.uk/agri-food-chain-directorate/the-regulation-of-genetic-technologies/supporting_documents/Gene%20Editing%20Explainer.pdf	Gene editing, genetic modification	None
The European Food Safety Authority (EFSA)	EU government	https://www.efsa.europa.eu/en/topics/topic/genetically-modified-animals	Genetically modified	Genetic modification video; highlighted definitions (e.g. risk assessment, DNA); cloning in animals
The Food and Drug Administration (FDA)	USA government	https://www.fda.gov/animal-veterinary/intentional-genomic-alterations-igas-animals/qa-fda-regulation-intentional-genomic-alterations-animals	Intentional genomic alteration (IGA), genetic engineering, gene editing	Freedom of Information Summary, Section IX; National Bioengineered Food Disclosure Standard; Federal Register with information about all IGA animals
Health Canada (HC)	CA government	https://www.canada.ca/en/health-canada/services/food-nutrition/genetically-modified-foods-other-novel-foods/approved-products/frequently-asked-questions-aquadvantage-salmon.html	Genetically modified and genetic engineering	New Substances Notification Regulations (Organisms) Regulations; The safety of genetically-modified food

Table 3 (continued)

Organization (abbreviation)	Organization type	URL	Terms used	Additional links provided
Global Justice Ecology Project (Global)	Environmental	https://globaljusticeecology.org/gene-editing-gmos-and-mutation-breeding-questions-and-answers/	Gene editing, genetic modification, genetic engineering	Detailed list of critiques, articles and reports addressing the potential dangers and risks of these emerging GE technologies
Roslin Institute (Roslin)	University	https://www.ed.ac.uk/roslin/about/dolly/facts/genetic-modification	Gene editing, genetic modification	Cloning FAQs; GM chickens that don't transmit bird flu developed; Gene-edited chicken cells resist bird flu virus; Gene-edited pigs show signs of resistance to major viral disease; Pig's genetic code altered in bid to tackle deadly virus; Learn more about the CRISPR/Cas9 system [yourgenome.org]
Wellcome Connecting Sciences (Yourgenome)	Educational	https://www.yourgenome.org/debates/is-it-ethical-to-genetically-modify-farm-animals-for-agriculture#q1	Genetically modified, genetically engineered terms used interchangeably	Highlighted definitions (e.g. selective breeding, transgenic)

[a]YourGenome was updated after the final version of this paper was accepted. The new URL is: https://www.yourgenome.org/theme/genomic-conversations-genetically-editing-animals-for-agriculture/

evaluation, *causal attribution* and *treatment remediation* (Entman 1993). The *problem definition* is the topic discussed and the actors identified. In this study, the FAQs topic was GE in farm animals, and thus we focused coding on the questions "asked" in the FAQs, including the topic and actors identified in the questions. The *moral evaluation* includes the benefits and risks of the topic and thus we coded how answers to the FAQs described risks or benefits of GE. C*ausal attribution* identifies who (actors) or what (factors) are responsible for the benefits or risks identified. Finally, *treatment remediation* identifies proposed solutions for the identified risks or calls for or against action on the topic. We followed Entman (1993, p. 52) in considering that "A single sentence may perform more than one of these four framing [elements]". Coding using frame elements allowed us to analyze how FAQs built their frames.

We used existing frames to code FAQs deductively. Our decision to use deductive frame analysis was motivated by the existing body of research that has identified frames used to portray novel biotechnologies; we applied these frames to GE in farm animals specifically (Foley et al. 2019). We identified existing frames from three articles published over the past 15 years on novel biotechnologies. The first was a systematic scientific literature review about the ethics of genome editing in non-human animals that identified the themes human health, efficiency, risks and uncertainty, public acceptability, animal welfare, animal dignity and species-specific capacities, and environmental considerations (de Graeff et al. 2019). The second was a frame analysis of biotechnologies described in *New York Times* articles published in the 1990s, identifying the themes of biomedicine, agri-food, research, economics, cloning, moral, public opinion, regulation and genetic identity (Matthes and Kohring 2008). The third was a frame analysis of public engagement events about synthetic biology in Europe from 2013 to 2017 (Bauer and Bogner 2020), identifying the frames of science, social progress, risks and control, ethics, economics and governance. Although authors used different data sources, they identified similar frames. Thus, we combined these into eight frames to use in our analysis: efficiency, risks and uncertainty, regulatory, animal welfare, animal dignity, human health, environmental considerations and public acceptability.

Briefly, the **efficiency** frame describes technologies like CRISPR as efficient, versatile, easy-to-use, precise and inexpensive compared to previous technologies, allowing for more rapid improvements in traits than is possible with traditional breeding, and reducing the risk of off-target effects. Thus, this frame portrays the technology as helpful in addressing societal challenges, and is safe for people, animals and the environment. By contrast, the **risks and uncertainty** frame describes potential negative consequences of the technology, including those difficult to predict, especially given incomplete knowledge about the traits altered. The **regulatory** frame presents laws, economic opportunities, risk assessments, public consultation and policy implementation. This frame can be presented neutrally or to align with the other frames already described. The **animal welfare** frame presents how GE affects animal welfare in positive or negative ways. Relatedly, the **animal dignity** frame discusses ethical considerations, including whether GE uses animals as objects to serve human needs and ignores their inherent value. The **human health** frame describes how GE addresses societal challenges related to human health, including increased food production, healthier and allergen-free products, and decreased risk of disease. The **environmental considerations** frame presents how GE could affect the environment in negative or positive ways. Finally, the **public acceptability** frame identifies reasons why the public may or may not support GE.

Frame Analysis

We assessed intracoder (consistent coding by one researcher) and intercoder (at least two researchers coding the same data) reliability (SAGE 2008). Intercoder reliability (in qualitative research, dependability) is used to offset a single researcher's interpretation of data and to perform analysis consistently within and across researchers (Guest et al. 2012). This is especially important in frame analysis because it involves "latent" coding, that is, coding that goes beyond what the text describes to include cultural and linguistic meanings that promote certain ways of thinking about the topic (Foley et al. 2019).

The first author uploaded frames and frame elements into NVivo (version 2019; QSR International; Burlington, MA), created descriptive codes for the frame elements and developed a codebook. She then recoded the documents 30 days later, revised the codebook and then a second trained qualitative researcher used the codebook to code the questions on each FAQs webpage to identify question topics and actors. The two coders met to discuss discrepancies and the first author revised the codebook and recoded the FAQs. The first author then selected two random question and answer sets (18% of the total dataset) which were coded again by the second coder. The two coders again met to discuss discrepancies and the first author made final adjustments to the codebook and then recoded all FAQs.

Results

We first provide a summary of the FAQs frames and then present how the FAQs frame GE questions and answers. We conclude with a description of how the public is represented in the FAQs. Quotes from the FAQs are italicized or indented, our added emphasis is identified by underline. Abbreviations (in parentheses) for the FAQs webpages (see Table 3) include: Acceligen (Acceligen), Biotechnology Innovation Organization (Biotechnology), Center for Science in the Public Interest (Center), Department for Environment, Food & Rural Affairs (DEFRA), The European Food Safety Authority (EFSA), The Food and Drug Administration (FDA), Health Canada (HC), Global Justice Ecology Project (Global), Roslin Institute (Roslin), and Wellcome Connecting Science educational website (YourGenome)[1].

We identified five of the eight frames in these FAQs: regulatory, efficiency, risks and uncertainty, animal welfare and animal dignity. The FDA, HC, and EFSA used the regulatory frame to describe their role in evaluating GE products and animals as well as protecting consumer safety through regulations. In contrast, Center and Global used the regulatory and risks and uncertainty frames, challenging the idea that regulations are adequate (given a lack of transparency in how these are developed), and suggesting that there are substantial risks associated with the technology given its novelty and the potential for unanticipated effects. DEFRA and Acceligen used the efficiency frame to focus on the benefits of GE for animals, people and the environment. Biotechnology combined the efficiency and regulatory frame, focusing on benefits and rigorous regulations. Roslin combined the efficiency and animal welfare frame, focusing on the benefits of GE for

[1] YourGenome was updated after the final version of this paper was accepted. The Results reported in this paper are based on the FAQs webpages accessed May 19, 2023.

animal welfare. Finally, YourGenome used the animal dignity frame, focusing on the ethical considerations of genetically engineering animals.

Regulatory Frame

The FAQs used the regulatory frame in two main ways: (1) as rigorous, science-based, and a means to provide consumer assurance about the safety of GE and (2) by challenging regulation adequacy and legitimacy.

Rigorous Regulations and Consumer Assurance

The FDA, HC, and EFSA mostly refrained from discussing the benefits or risks of GE and instead focused on the rigorous regulations used to evaluate GE animals and products. Accordingly, a prominent actor and question theme is the conveyance of government as responsible for these regulations and defining and evaluating GE animals and products. For instance, EFSA used words like *"comprehensive"* and *"clear"* and the FDA described their regulatory system as *"science and risk based."*

Regulations were also described as a method to mitigate technology risks. For example, HC described that new agricultural or food products are *"subjected to thorough safety assessments to protect humans, animals and the environment."* This was described as involving a scientific literature review, government oversight, data evaluation and product assessment by HC, the Canadian Food Inspection Agency and Environment and Climate Change Canada.

Regulations were also connected to consumer safety. For example, in response to the long-term health impacts of eating genetically modified foods, HC stated that *"genetically modified foods are subject to a far higher level of regulatory oversight*" and that GM food must pass a *"thorough and robust safety assessment before it is allowed on the Canadian market*." HC's focus on providing rigorous regulations to protect consumer safety is reiterated with a hyperlink to *"The safety of genetically-modified (GM) foods."*

Although GE farm animals are not currently allowed in the European Union, EFSA's FAQs attributed their "*proactive*" development of a *"risk assessment of food and feed derived from GM animals"* to scientific advancements. In this case, the risk assessment is described as a *"proactive measure to assure consumer safety.*"

DEFRA and Roslin also connected regulations to consumer safety and assurance. For example, DEFRA asked: *"Will consumers be unsure about what they are eating or drinking and whether it is natural?"* and answered: *"There will be no weakening of our strong food safety standards."* Other questions, for example, *"Does this mean that "frankenfoods" are now on the menu?"* were answered by a single word: *"No"*, followed by explanations about food safety standards. Similarly, Roslin assured: *"There is no reason to think that the process of genetic modification in food products would be unsafe."*

A prominent causal attribution used by Acceligen, Biotechnology, DEFRA, EFSA and HC to describe the safety of GE food is that there are no substantive differences between GE and conventionally-bred animals. For example, EFSA wrote: *"Experts will assess whether food and feed from GM animals are as nutritious to humans and animals as those from conventionally-bred animals"*, DEFRA explained that *"gene editing makes the same types of changes to plants and animals that occur naturally and through traditional breeding"* and Acceligen argued that "*The dairy and meat products from gene edited animals are identical to those coming from non-edited animals."* Center, however,

challenged this similarity, stating that *"There will be a need to ensure that eating the meat or drinking the milk from the engineered animal will be safe."*

Going beyond consumer safety, Biotechnology acknowledged the importance of consumer trust and linked this to regulations. Specifically, they asked: *"Why regulate GE animals and their products?"* and responded that an "*internationally recognized approval process*" will be part of ensuring consumer acceptance and efficiently commercializing GE products. As well, they stated that FDA guidance is similar to the Codex Alimentarius (international "food code" compiled by the Food and Agriculture Organization and the World Health Organization) that provides international standards for GE animals. In summary, these organizations assure consumers about the safety of GE by referring to science-based regulations, and in some cases, by emphasizing the similarity of GE to conventionally-bred animals.

Challenging the Adequacy of Regulations

Instead of describing regulations as rigorous and a means to assure consumer safety, Global and Center used a risks and uncertainty frame. One concern was the fast pace of technology relative to regulatory processes. Global asked: *"Are there any gene-edited plants or animals already on the market?"* and answered: *"The industry is hoping to move very fast, and counts on bypassing EU GMO laws to sell the GM seeds into Europe as well."* This answer was connected to insufficient regulations, as demonstrated in responses throughout the FAQs, for instance: "*there has been no or little assessment of the biosafety implications"* and *"If gene-edited organisms were to escape EU GMO regulations, any potential negative effects on food, feed or environmental safety would go unchecked."*

Global's proposed solution to the lack of adequate regulations was using existing laws and risk assessment methods to evaluate newer technologies. In response to a question about whether gene editing can create a naturally occurring change in an organism, their answer alluded to the potential for "*unintended changes*" and concluded, *"In practice, this is one of the main reasons why risk assessment of GMOs is carried out – in order to determine if any unintended changes have implications for food and environmental safety."*

Center also questioned regulation adequacy and the FAQs mentioned environmental risks and causally attributed these to insufficient regulations. For example, Center asked, *"Is the federal regulation of GE animals adequate?"* and responded: "*While the FDA has the expertise to address food-safety questions*, *it has less expertise in analyzing environmental concerns presented by GE animals."*

They continued by encouraging the "*expertise of agencies (e.g., Environmental Protection Agency)"* to be included in regulations.

Unlike the FDA, HC, and EFSA that attempted to assure consumer safety concerns through regulations, Center focused on a lack of regulatory transparency. Throughout the FAQs webpage, they emphasized the "unknowns" involved:

> The next GE animal on the horizon after the salmon is unknown. … it is unknown how far along those products are toward commercialization. The FDA is prevented by law from discussing pending applications (see Question 34 for criticisms of the regulatory system).

A lack of access to information was also presented as a risk. In response to the question, *"Is the federal regulation of GE animals adequate?"* Center answered that while the FDA was reviewing applications for GE animals, "*the public may not know what is going*

on or have the opportunity to provide its input into the FDA's decision." Center's concern is that the public is unable to access information about GE animals and the approval process. This concern about transparency is causally attributed to government and their imposition of confidentiality: "*Congress imposed on the FDA strong confidentiality provisions surrounding animal (and human) drugs, which shroud the approval process in secrecy and greatly limit access to information or any opportunity for public participation until the drug is approved."* Despite these concerns, Center proposed a solution that would make the process more transparent and participatory, which included Congress eliminating *"confidentiality requirements"* so data could be reviewed by *"outside experts"* and requiring a formal *"public comment opportunity."* Here, organizations criticize existing regulations by highlighting a lack of clarity, unknown consequences and inability to protect human, animal and environmental safety.

Efficiency and Risks and Uncertainty Frames

The FAQs framed GE as an efficient technology or one that is risky and uncertain largely by: (1) comparing GE to other breeding practices and (2) defining GE technologies.

Comparing GE to Other Breeding Practices

Organizations compared GE to other breeding practices to describe the technology. The efficiency frame involved explaining how GE is a logical progression in breeding technology that is already well established. FAQs also described how technologies like CRISPR were faster and more precise than traditional breeding. For example, Roslin asked, "W*hy do scientists change DNA?"* and described that "*selective breeding was in use for thousands of years before the genetic mechanisms of inheritance were understood*" and that new tools to analyze DNA have made the process "*faster and more precise."* Similarly, DEFRA began their FAQs by explaining how technologies enabled *"genes to be edited much more quickly and precisely to mimic the natural breeding process."* Global, however, challenged the comparison of newer GE technologies to older ones by describing the risks involved: "*Given that these techniques are new, it is not yet possible to fully evaluate the potential for adverse effects."* In these examples, organizations contrast in their presentation of GE as a well-established or novel technology.

Defining GE Technologies

The FAQs used different technology terms (Table 3). While the efficiency frame focused on the similarity of GE to traditional breeding practices, it also applied this frame in ways that distanced GE from other technologies like genetic modification. For example, consider how DEFRA distinguished the different technologies, seemingly confounding these with cis- and trans-genesis:

> Gene editing should not be confused with genetic modification (known as GM). Genetically modified organisms are those where DNA from a different species has been introduced into another. Gene edited organisms generally do not contain DNA from different species, they contain changes that could be made more slowly using traditional breeding methods.

Five of Acceligen's 11 questions addressed differences between gene editing, genetic modification and transgenesis and emphasized that gene editing and genetic modification are *"entirely different."* Acceligen asked: *"How is precision breeding different from traditional breeding or GMO?"* and responded with the example of polled (i.e., hornless) cattle: *"The ability to use CRISPR allows us to speed up the process of selection without the use of transgenes."* Thus, emphasizing differences and drawing linkages between new and old technologies appeared to be important for these organizations.

In contrast to organizations distancing themselves from certain terms, Global asked questions that compared gene editing, "old-style" GMOs and mutation breeding, including whether "*gene-edited plants and animals are as risky as 'old-style' GMOs."* Questions that compared gene editing and GMOs provided an indication of how Global defines the problem and evaluates risks about this technology. To demonstrate, Global asked: *"Isn't gene-editing much more precise than 'old-style' genetic engineering?"* and responded: "*Gene-editing is theoretically more precise in the positioning of the intended alteration to the genetic material, compared to the insertion of genes at random locations that is characteristic of previous techniques. But how this altered DNA will affect interactions with other genes and processes within the cell is largely unknown.* The words "*theoretically*", "*but*", and *"largely unknown"* challenge the claims of precision used by other organizations. This answer went on to describe implications of gene editing for food, animal feed, and environmental safety in terms of potential toxic compounds, reduced nutrition, and new allergens (i.e., consumer safety concerns).

Animal Welfare and Animal Dignity Frames

The FAQs used the animal welfare and animal dignity frame in two main ways: (1) by presenting animals as the objects of GE regulations and referring to existing animal protection regulations and (2) by discussing the benefits and risks for animals.

Animals as the Object of Regulations

The FDA and EFSA discussed animals in terms of how they are, or would be, regulated. For example, EFSA described that they would account for the health and welfare of animals through guidance documents designed to assess and monitor genetically modified animals. The documents include *"extensive comparison"* of GM animals to conventional counterparts. The FDA referred to animals in all but one of their questions which included explaining regulations, animal use on farms and in research, and comparisons to conventional counterparts and clones. Thus, while animals were sometimes featured in questions, the question themes related back to regulations.

Some FAQs emphasized how GE animals were monitored by animal welfare laws and standards (e.g., DEFRA, Roslin). YourGenome acknowledged the benefit of animal welfare regulations in place in the United Kingdom (e.g., *Animal Welfare Act*), but also described risks, including that regulations were insufficient because GE is new and thus few regulations refer to farm animals specifically. YourGenome noted that the FDA *"monitors and maintains certain standards, including input from the public, when it comes to genetically engineering animals."* Biotechnology included that research institutions place the well-being of genetically engineered animals *"as a top priority"*, follow the USA *Animal Welfare Act*, and in some cases, follow third party and international welfare guidelines. Biotechnology also presented their "*Guidance for Genetically Engineered*

Animal Stewardship Initiative." The initiative promotes animal welfare, enhances credibility, and provides guidance for biotechnology organizations. In these instances, organizations may be seeking to provide public assurance about the welfare of GE animals.

Benefits or Risks for Animals?

FAQs that used the efficiency frame focused on benefits for animals. For instance, Biotechnology asked: *"How does genetic engineering affect animal welfare?"* and responded:

> Genetic engineering has the potential to greatly improve the health and welfare of agricultural animals. GE animals may be disease resistant, parasite resistant, and withstand stress. The beneficial trait can likely improve their well-being because they will be more productive.

Like the description of regulations to protect animal welfare above, describing the potential benefits for animals may also convince FAQs readers that GE is positive for animals.

DEFRA, Acceligen, and Roslin discussed the benefits of GE for animals, humans and the environment. For example, Roslin asked: *"Why do scientists change DNA?"* and answered: "*We are using these genetic tools to improve animal welfare, promote global food security, and reduce the impact of animal disease on farmed animals and humans."* DEFRA and Acceligen contextualized their responses by writing that some animals struggle in current conditions due to disease or climate change; for example, suggesting that the technology could generate animals with traits better suited to changing environments and disease threats (e.g., swine fever, avian flu). Specifically, Roslin presented the monetary cost of avian influenza in 2015 in the USA alone (390 million dollars). DEFRA and Acceligen noted that increased use of these technologies could lead to improved climate resilience in alignment with the United Nations Sustainable Development Goals. These examples show how GE is positioned as beneficial for animal welfare, sustainability, and necessary given economic and disease hardships.

Two FAQs provided counter arguments to animal welfare benefits by acknowledging animals may be harmed. Roslin asked: *"Does genetic modification or gene editing harm animals?"* and responded: "*Some changes to an animal's DNA can be potentially harmful to the animal, such as changes that cause the animal to develop a disease, which might be carried out so that scientists can learn more about the condition."* In another example, Center did not highlight benefits of GE for animal welfare and instead asked, *"Do GE animals pose health or environmental risks?"* and responded: "*Engineering animals may also raise ethical or animal welfare concerns, such as whether the adding of a gene somehow causes the animal to suffer pain or reduce its quality of life."*

YourGenome approached their FAQs differently and answered each question by presenting benefits and risks for animals. In response to the question, *"Is genetic modification of farm animals ethical?"* the answer listed animal welfare benefits including disease resistance and polled genes. Risks listed included animal harms, for example: *"transgenic pigs were found to be arthritic, partially blind"*, and "*new diseases from genetically engineered animals could be spread to non-genetically engineered animals, and even humans."* Acknowledging that animals may suffer or could be harmed may be an attempt by organizations to be transparent about GE technologies.

Alongside animal welfare risks, YourGenome addressed concerns around animal dignity, including that embryos used in research may not survive and that GE violates animal rights. A proposed solution was using non-animal alternatives in research including plants and bacteria. Thus, the animal dignity frame focused on the animals themselves and not as objects for human use.

Public Representations

FAQs represented the public using varied pronouns and terms, addressing information access and discussing public consultations.

The public were featured differently in terms of linguistic and jurisdictional scope. For example, the FDA referred to regulations of GE for broad societal uses including food and pharmaceuticals. EFSA referred to the public indirectly by asking: "*What about the ethical concerns surrounding GM animals?"* and clarified such concerns are outside of their jurisdictional scope. Here, the organizations seemed to be distancing themselves from addressing certain ethical questions about GE.

FAQs used the term "public" (Center, EFSA, YourGenome), "consumers" (Acceligen, Biotechnology, DEFRA, HC, Global), and the FDA and Roslin combined terms and used pronouns. For example, HC asked: *"How can* I *tell if a food has been genetically modified?"* and Center asked: *"Will GE animals and their products become part of our food supply?"* These questions are written as if people actually asked the organization the question, but none of the FAQs described who posed the questions or how the organization chose which questions to address.

Some FAQs demonstrated what organizations considered the public knows and most (all but DEFRA and Center) provided links to more information (Table 3). For instance, the FDA addressed what the public may have encountered online about GE animals. They asked, *"Does introducing an intentional genomic alteration (IGA) into an animal cause it to look different from other animals without IGAs?"* and responded: *"Despite some of the doctored photographs that you may have seen circulating on the internet, making an intentional genomic alteration to an animal does not result in outlandish physical combinations, such as a bird with the head of a rabbit."* This may be an attempt to address and combat what the FDA considered misinformation about GE.

HC addressed freedom of choice, specifically that people choose which products to buy or grow and mentioned that voluntary labelling provides information about GE food. They also described transparency about genetically engineered products as a way to address public concerns, stating that they *"provide consumers with access to meaningful, credible, and truthful information as it relates to biotechnology and food."* Similarly, the FDA asked: *"How will the FDA inform the public about new IGAs in animals, its decisions on them, and the science behind those decisions?"* They responded that people could visit the FDA website for more information. Finally, DEFRA described their ongoing public consultation as "*an opportunity for people to voice any concerns they may have."* In these instances, each government agency acknowledges the public as being potentially interested in learning or expressing concerns about GE.

Discussion

Organizations utilized FAQs to present and frame information about GE to the public. Our discussion connects our frame analysis to the concept of trust in public perceptions of GE and comparisons between GE technologies. We also provide recommendations for future

research and how FAQs might be improved based on actual public questions and how the public and animals were represented.

Some organizations used the regulatory frame to enhance or diminish trust in the technology. Trust, including trust in GE technology regulation, has received considerable research (Frewer et al. 2013), with results showing that people tend to perceive technology as more acceptable if they trust the institutions responsible (Siegrist 2021). Thus, framing tied to trust (or mistrust) in regulations can be expected to affect public acceptance. We acknowledge that four of the ten FAQs were from government institutions, and although the countries regulate GE differently, they used the regulatory frame by emphasizing rigorous regulations and consumer food safety. Future research might explore other sources of grey literature, including reports, position papers and policy briefs, that provide information about how other organizations frame GE. As well, we were unable to collect data about the purpose of the FAQs from the organizations themselves. This perspective could be explored in future research. We also encourage organizations to clearly state the purpose of their FAQs and describe how these incorporate actual public questions.

The efficiency and the risks and uncertainty frames both drew on comparisons between old and new technologies, compared GE to traditional breeding and discussed the differences between technology terms. Describing differences and similarities between gene editing and older technologies for genetic engineering is common within the public sphere (Meyer 2020) and some have encouraged distancing CRISPR from earlier technologies to avoid public opposition (Doxzen and Henderson 2020). Public perceptions research focused on GE plants has shown that the term genetic modification is perceived more negatively than genome editing (e.g., Bearth et al. 2022; Zahry and Besley 2019), and that transgenesis is perceived more negatively than cisgenesis (Kronberger et al. 2014). Recent research on GE in farm animals, however, found participants expressed a similar understanding of what GE technologies do (i.e., change an organism's DNA), and used verbs (e.g., edit, modify, alter) interchangeably (Koralesky et al. 2023).

In this paper we used the term genetic engineering because it broadly describes technologies that modify an organism's DNA. We acknowledge, however, that terms have been introduced over time (e.g., genetic modification in 1993; genome editing in 2003; Montoliu 2023). In the public sphere (and several FAQs including those of Acceligen, Biotechnology, DEFRA and Roslin), gene editing using CRISPR-Cas9 is presented as "precise", and this has generated a narrative that an organism's genes can be controlled via technology (Shah et al. 2021). Thus, the use of certain technology terms may be an attempt to diminish (or accentuate) existing concerns about GE.

The FAQs used different terms to represent the public. FAQs formulated questions as if people were asking them, using the pronouns "I", "we", and "our"; however, it was unclear who the pronouns were referring to. Indeed, FAQs did not specify how questions were generated and by whom. Arguably this general approach could be viewed as collapsing various publics into a single group, whereas in reality, different people will look at topics in different ways (Rempel et al. 2019). This is perhaps another opportunity where organizations seeking to engage publics might solicit actual questions (Kuo et al. 2024) or acknowledge that different views exist by presenting the potential benefits and risks of GE for animals, similar to the approach used by YourGenome.

FAQs reflected the types of issues that organizations wished to engage with; for example, EFSA refrained from discussing public engagement, considering ethical debates outside of their jurisdiction and Roslin, Global, and Acceligen did not discuss public input. Center focused on a lack of transparency about GE and emphasized that the public *"may not know"* which GE products are being developed. DEFRA, Roslin, and YourGenome discussed

animal welfare regulations in place for GE animals, and Biotechnology presented their animal stewardship program, perhaps in an attempt to address concerns about animal welfare; some organizations (Acceligen, Biotechnology, DEFRA, Roslin) also presented potential benefits for animal welfare. Two organizations (Centre and Roslin) noted potential harms to animals, perhaps in an attempt to be transparent about GE technology development.

Our study illustrates the different ways animals are featured in FAQs. The FDA, HC, and EFSA featured animals as objects of regulation and YourGenome, Biotechnology, and Roslin considered increased production as a result of GE to have animal welfare benefits. YourGenome considered animal dignity, and in one question and answer, Roslin and Center mentioned unknown outcomes and potential suffering. Early animal welfare research connected increased production to better welfare, but this association is now considered naive (Fraser 2008, pp. 102–103). More recent work suggests that people are unlikely to approve of GE simply to improve production (Naab et al. 2021; Nuffield Council on Bioethics 2021) and generally do not want to see animals harmed by technologies (McConnachie et al. 2019).

Our study, and much of the previous work on public perceptions of GE, focused primarily on organizations from Europe and North America (Frewer et al. 2013). We acknowledge cultural differences exist in these contexts, and echo Feliú-Mójer's (2020) call for public engagement to include underrepresented communities, ideally using participatory research methods. Recent work by Munshi et al. (2016) illustrates how more inclusive approaches can be used. We suggest that these approaches, for example, incorporating different languages and multiple viewpoints, be incorporated into public engagement activities about GE including FAQs. These approaches would also respond to calls for making public engagement efforts meaningful for the individuals involved, for example considering ways to directly link public engagement to the policy-making process (Scheufele et al. 2021).

Conclusion

We described how FAQs framed GE in farm animals. The regulatory frame featured prominently, with some FAQs emphasizing comprehensive regulations focused on consumer safety and others questioning regulatory adequacy. The efficiency and the risks and uncertainty frames contested differences between older and newer technologies. Animals were discussed largely as an object of regulations, but some FAQs also discussed benefits and risks for animals, including threats to the animal's dignity. Different FAQs webpages represented the public differently, but within each the public was considered as a single group.

Acknowledgements We thank Christine Kuo for her assistance with analysis. We thank Katherine Miller, UBC librarian, for sharing her knowledge about grey literature reviews. We are also grateful to our colleagues at UBC and the University of Guelph, including Dr. Mike Von Massow and Jennifer Leslie for their help and support with this project.

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Funding This work was funded by the Government of Canada through Genome Canada and the Ontario Genomics Institute (OGI-191). The companies Semex and Acceligen are industry partners to the Genome Canada grant. They were not involved in the study design, collection, analysis, interpretation of data, the writing of this article or the decision to submit it for publication.

Data Availability We have supplied the Uniform Resource Locators (URL) for each FAQs webpage in Table 3 in the main text of the manuscript.

Declarations

Ethics Approval This study did not require ethical review from the University of British Columbia Behavioral Research Ethics Board because according to the Tri-Council Policy Statement 2 2022, article 2.2, it relied on information that is "in the public domain and the individuals to whom the information refers have no reasonable expectation of privacy". The TCPS2 is available here: https://ethics.gc.ca/eng/policy-politique_tcps2-eptc2_2018.html.

Consent Not applicable (see statement on Ethics approval).

Employment Not applicable.

Competing Financial or Non-Financial Interests The authors have no relevant financial or non-financial interests to disclose.

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