Final report

Community Attitudes toward Gene Editing in the Red Meat Sector

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Abstract

This study was conducted to better understand the diversity of community and producer attitudes toward the use of gene editing in red meat production, and to explore the drivers and implications of these attitudes for community engagement on this topic. The purpose of the research was both to better understand how and why Australians hold particular views on the use of gene editing in meat production and, through such understanding, to develop a set of best practice guidelines for community engagement on this topic. To achieve the research objectives, we conducted a mixed qualitative and quantitative study which consisted of a series of community focus groups, stakeholder interviews, and a producer survey, which helped inform a subsequent large-scale community survey. As a result, we identified five community discourses on gene editing, which were partly associated with general views on livestock production and technological innovation. We also explored key issues related to community trust and proposed best practice guidelines for engaging members of the community about gene editing. The results of this research will assist MLA in responding to the public's hopes for and concerns about the use of gene editing in livestock production.

Executive summary

Gene editing is a relatively new approach for manipulating livestock DNA, which could provide a more precise and rapid way to introduce genome alterations in livestock species, and thereby contribute to gains in animal welfare and health, environmental sustainability, and productivity. However, little is currently known about community attitudes toward gene editing, and particularly its prospective use in livestock production. Without an in-depth understanding of the community's attitudes toward editing and their underlying values, the livestock industry's social license to operate (SLO) may be challenged if gene editing is used. Understanding the opinions of the Australian community is crucial to developing proactive strategies to foster alignment between producers, scientists, policymakers, regulators, and community members with regard to whether and how gene editing should be used in Australian red meat production.

This study examined community and producer attitudes and values related to gene editing technology and its prospective application in beef and sheepmeat production, as well as the drivers of these attitudes, and their consequences for community engagement on this topic. The purpose of the research was both to better understand how and why Australians hold particular views on the use of gene editing in meat production and, through such understanding, to develop a set of best practice guidelines for community engagement on this topic.

To achieve the research objectives, we conducted a mixed qualitative and quantitative study which explored community attitudes, related drivers of community views, and their implications for the Australian red meat industry. The research consisted of a series of community focus groups, stakeholder interviews, and a producer survey, which served to collect and characterise diverse attitudes toward gene editing. The prevalence and distribution of the identified attitudes, as well as related drivers, were subsequently explored by means of a large-scale, representative community survey.

Both our qualitative and quantitative findings highlight the diversity of attitudes toward the use of gene editing in livestock production within the Australian community. Following a Q-methodological approach, we identified and characterised five community discourses on gene editing, one of which is generally optimistic about the potential benefits of gene editing, while the other four are either conditionally supportive or opposed to the technology and its use in livestock production. The community survey revealed patterns in the distribution of the identified discourses, as well as correlations between these discourses and existing attitudes toward livestock production and technology.

Although producers were generally more positive about gene editing, they shared many of the community's concerns about gene editing and its application in red meat production. Producers emphasised the need to prioritise animal welfare in the application of gene editing, but had much more positive views on altering temperament particularly in comparison to the community responses.

Both the focus groups and survey provided insights into the community's trust in stakeholders involved in gene editing. Overall, the most trusted stakeholders in gene editing in livestock are scientists, but this trust is lower where either funding or research interests are perceived as aligned with promoting gene editing. Further, different actors are trusted to do different things, so that although producers may not be trusted to regulate the use of gene editing in livestock (because of potential vested interests), the community wants to hear their perspectives because of their expertise and experience.

The results of this research will assist MLA in responding to the public's hopes for and concerns about the use of gene editing in livestock production. The findings give a window into some of Australians' concerns about red meat production, and particularly trade-offs between animal welfare, production efficiency, and environmental issues, which might be heightened by the eventual introduction of gene editing.

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The study has been approved by the Human Research Ethics Committee at the University of Adelaide (approval number H-2020-132).

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1. Background

1.1. Introduction

Gene editing (see Box 1) is a relatively new approach for manipulating DNA, and hence changing the genetically-determined characteristics of organisms to suit particular purposes. Meat and Livestock Australia (MLA) has been closely engaged with research occurring globally on uses of gene editing in livestock, particularly cattle and sheep, in concert with its ongoing efforts to support producers to gain knowledge about and improve their approaches to livestock genetics via breeding values and other strategies. Gene editing for particular traits of interest could provide a highly controlled, more precise, and rapid way to introduce genome alterations in livestock species.

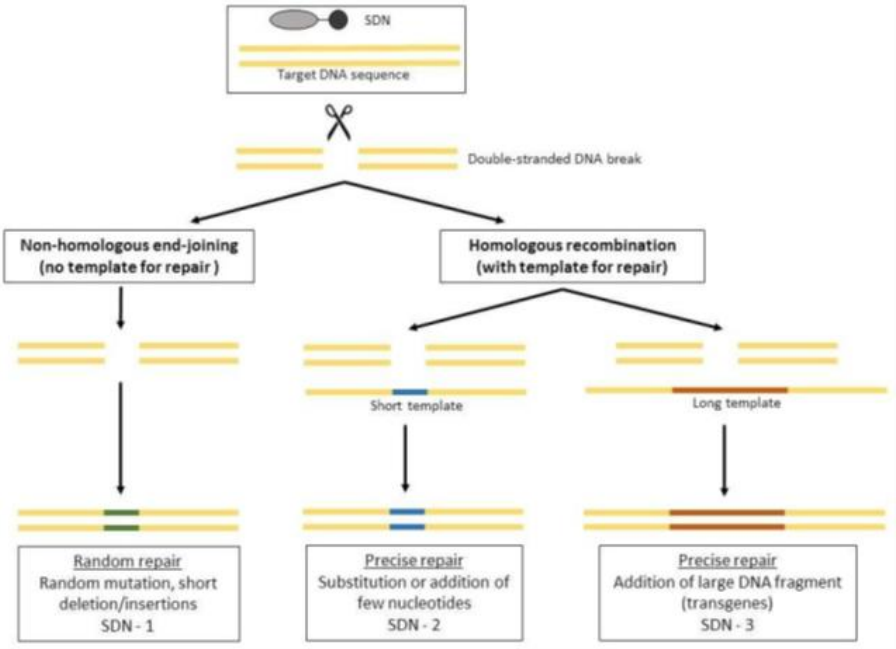
Scientists are optimistic about various types of gene editing technology, and suggest that it has the potential to address a number of issues in animal production, including increasing disease resistance, reducing the threat of zoonotic disease transmission, improving the sustainability and efficiency of production, and improving animal welfare through modification of specific traits (see e.g., Perisse et al. 2021). They point to the continued need to meet global demand for meat products as well as the need to make improvements to the efficiency of animal production including for environmental and welfare reasons. Given previous strong public resistance to the development and use of genetically modified animals for food production (with only one genetically-modified animal ever reaching commercial production), many scientists hope that gene editing will be found more acceptable, particularly as gene editing may be used to endow animals with characteristics which may be beneficial for their own welfare or for the environment, goals which are broadly viewed as more likely to be acceptable to the public. Some scientists also have suggested that because some gene editing techniques do not require the introduction of exogenous DNA, they will be more acceptable to the public than previous technologies. However, there is little empirical evidence to support these types of claims. What little evidence is available (as described further below) suggests that gene editing in animal production will be evaluated as a novel technological intervention but one which shares a history or genealogy with earlier genetic modification (GM) techniques, as well as within the broader context of larger-scale animal farming which is coming under increasing public scrutiny including in Australia.

Despite the rapid advancements in the science and particular applications of gene editing to livestock, we have extremely limited information about what communities think about its use (a limited number of studies have emerged about gene editing in locales outside Australia since this project began such as Yunes et al. 2021 on Brazilian attitudes), and no detailed studies have previously been conducted in Australia on gene editing in livestock. Hence before the livestock industry considers supporting and introducing gene editing into its practices, it is critical to have a better understanding of what people's concerns and hopes are for this technology and the diverse types of applications for which it might be used.

Box 1: What is gene editing?

Gene editing is a laboratory technique where targeted changes are intentionally made to the genetic code (DNA) of an organism, such as plants and animals (see Figure 1). Gene editing is done to change the traits of the organism by either removing, adding, or exchanging genes or parts of genes. One way that gene editing could be used is to speed up changes in animal traits that could otherwise be achieved through traditional selective breeding, by introducing the genetic information from another breed of the same species or by 'turning on' or 'turning off' existing genes within a breed. Edited genes are potentially inherited by the next generation and can be used to pass on the trait throughout a herd or flock.

Figure 1: Illustration of the types of processes involved in gene editing
Image courtesy of C. Ramage used with permission (adapted from Podevin et al. 2013).



It is now widely recognised that maintenance of the so-called 'social license to operate' (SLO) is critical across a range of industries, particularly in agriculture. SLO refers to the idea that acceptance of practices is implicitly granted to a company or industry by the community, particularly where the industry uses public resources such as land and water (e.g., Gallois et al. 2017), or is viewed as having broader responsibilities (e.g., to treat animals humanely). As is often noted, SLO is difficult to gain and easy to lose, particularly if a company or industry seems not to be knowledgeable about or engage with community concerns or prioritises profits over responsibilities. SLO critically depends on ongoing negotiation, including close attention to underlying values, language, and concepts. Thus it is very important to explore what the community thinks about new technologies early in the processes of considering their future introduction in order to prioritise technologies based both on their scientific and their social promise, as well as to develop tailored public engagement strategies. Understanding the views and values of the Australian community also is crucial to developing proactive strategies to foster alignment between producers, scientists, policymakers, regulators, and community members with regard to various uses of gene editing.

To inform MLA's investment and engagement, is it vital to examine current Australian attitudes to gene editing in the red meat industry. Hence this project was conducted to better understand how members of the Australian community perceive the prospective use of novel gene editing technologies in the Australian beef and sheepmeat industries. The aim of this research was to provide a rigorous and rich exploration of community values and viewpoints to allow a deeper understanding of shared and diverging attitudes within the Australian community. Furthermore, we aimed to develop an evidence-based program using best practices in community engagement to facilitate communications with community members, policymakers, and other stakeholders about potential uses of gene editing in livestock.

To do so, this study applied a range of social science methods to collect and analyse community and producer views. The project methods were guided by Q-methodology (details of which are provided below). The specific processes involved with gene editing as well as its intended uses specifically in livestock may raise distinct issues from those that were the main foci in previous debates (e.g., in association with GM) and it cannot be assumed that attitudes will be the same across technologies, applications, or locations. Thus, we used detailed scenarios as well as facilitated discussion to probe people's responses and understandings of particular potential applications of gene editing to livestock.

What follows is a summary of the research literature that informed the current investigation; in particular we highlight the gaps in existing knowledge that we seek to address. We have also included research that has been published after the commencement of this research project to position our research against the backdrop of the most recent information in this rapidly changing field.

1.2. Attitudes to gene editing in food and livestock in Australia

There are very few reports in either the scholarly or grey literatures that provide insights into Australian community attitudes to gene editing in food production. However, the available evidence suggests that the awareness of gene editing is very low and hence the issue has little salience within the broader community. The Office of the Gene Technology Regulator (OGTR) has been conducting regular surveys of community attitudes to gene technology since 2015, with the 2017 survey being the first to include questions on gene editing. In the most recent available survey (Cormick and Mercer 2019), 48% of respondents stated that they had "heard of it but knew little or nothing about it," 13% of respondents stated that they could explain it to a friend, and another 32% stated that they had never heard of it. These results indicate a much higher level of awareness than what was found in the only peer-reviewed study of Australians' attitudes to gene editing in food, where 12.6% of the 444 Australians who participated in a five-country study responded that they had "heard of" CRISPR (Shew et al. 2018). The awareness of gene editing is lower than awareness of GM, but it appears that knowledge of GM is decreasing (Cormick and Mercer 2019), with only 22% of respondents knowing "… enough to explain to a friend" and 56% of respondents having "heard of it but know very little about it" in 2019.

Although awareness and knowledge are low, Australians appear generally more accepting of gene editing than GM (Cormick and Mercer 2019). Just over half of respondents (52%) thought gene editing–defined as "making a small change to an existing gene within a plant"–might improve our way of life in the future as compared with 45% of respondents for the use of GM. When comparing different gene technologies, cisgenesis (defined as "introducing the genes of a plant of the same species") and gene editing ("making a small change to an existing gene within a plant, as done in gene editing") were considered most acceptable, with 46% and 36% of people respectively rating them as highly acceptable (7–10 on a 10-point Likert-type scale). However, acceptability is much lower for various transgenic options with the lowest level of acceptability (0–3 on a 10-point Likert-type scale) being for using genes from animals (29%).

There is only one study that explores Australians' attitudes to gene editing of animals for food, which shows that public attitudes and support for gene editing across multiple applications, including medical therapeutics, are dependent on the type and details of the application as well as on individual demographic differences such as gender and ethnic identity (Critchley et al. 2019). In a survey of 1004 Australians, this study found that support was significantly lower for the use of gene editing of animals for food in comparison to gene editing for the purpose of enhancing human health, although it was slightly higher than for human enhancement. These results follow from research demonstrating that Australians have relatively low levels of support for GM used for enhancement of animals for food and humans (so-called 'designer babies') (Marques et al. 2015).

Australians appear as willing to consume plant-based foods produced with gene editing as those produced with GM. Shew et al. (2018) found that just over half (51%) of Australian respondents (n=431) in their multi-country study were willing to consume both GM and CRISPR rice modified for glyphosate resistance, the second highest percentage after the US. There was no statistical difference between Australian participants' willingness to consume foods produced using CRISPR or GM technologies. There have been no studies that examine Australians' willingness to consume products from gene-edited animals. Willingness to consume GM animals has remained relatively steady but low over the past four years, with only 29% of the respondents in the 2019 OGTR survey willing to eat products from GM animals (Cormick and Mercer 2019).

In summary, the available quantitative results on Australian attitudes and views are difficult to interpret and provide limited information, particularly about attitudes specifically toward gene editing applications in livestock. There are suggestions that the particular application of a technology may be especially important, and that Australians may well consider GM and gene editing to be similar kinds of technologies which raise the same issues and concerns.

1.3. Responses to gene editing in food and livestock overseas

A small number of international studies have reported on awareness, knowledge and perceptions of gene editing in food, mostly in the context of willingness-to-pay (WTP) studies. Of these, only a few thus far have sought to uncover attitudes toward gene-edited food; even fewer specifically focus on gene-edited animals or livestock and in some cases the associated food products (e.g., McConnachie et al. 2019; Yunes et al. 2019; Vasquez Arreaga 2020). Hence what we know about this topic is based on limited data.

1.3.1. Awareness and knowledge

All overseas studies to date which have compared gene editing and GM show that awareness of gene editing is lower than awareness of GM, similar to the situation in Australia.

The previously mentioned study by Shew and colleagues (2018) examined awareness of gene editing (specifically CRISPR) as well as willingness-to-consume (WTC) in the USA, Canada, Belgium and France in addition to Australia, based on a sample of 451 to 499 participants in each country. In all countries, more participants indicated that they had heard of GM (ranging from 51.7% to 73.7%) than had heard of CRISPR (10.2% to 20.2%). Australians had the second highest awareness of GM (68%) behind Canada and the second lowest awareness of gene editing, behind France. Lower awareness of gene editing when compared to GM has also been found in South Korea (Son and Lim 2021), the adjoining regions of East Flanders and Southern Netherlands in Belgium and the Netherlands (Ferrari et al. 2020), and the US (Caputo et al. 2020). Between country comparisons are rare, but in addition to Shew et al. (2018), Marette et al. (2021) found that 66.9% of US participants were aware of food innovations and biotechnologies, including gene editing, as compared with 46.3% of French participants.

Understanding levels of awareness or gauging the salience of gene editing can be useful for the development of community engagement strategies. However, having knowledge *of* a technology is very different to knowing *about* a technology in any detail or being deeply engaged in the issues associated with it. There is considerable debate in the scholarly literature, mostly based on research on attitudes to GM, about what *kind* of knowledge is important; what aspects of gene technology are important to know *about;* whether knowledge is related to other factors such as attitudes, acceptance, or behavioural responses; and, if knowledge is related to those factors, what direction is causal. The context of that knowledge and its relationship to other types of knowledge and beliefs will also be of central importance.

Knowledge can be determined through either self-report (measured by participants rating their own knowledge on a scale) or via objective tests. Ferrari et al. (2020) report that millennials and members of Generation Z in Belgium and the Netherlands gave themselves mid-level scores for both gene editing and GM and this was highly correlated with "objective" knowledge as assessed by scoring answers to bimodal, true or false statements. Caputo et al. (2020) note low levels of self-assessed knowledge in their US study (36% considered themselves unknowledgeable about gene editing), and found that participants in treatment groups that received information about gene editing then had better objective knowledge than the control group who did not receive information.

In almost all studies examining gene editing, participants were provided with some definition of gene editing or new breeding techniques (NBTs), in an attempt to discriminate it from GM. This limitation in experimental design makes it difficult to determine whether community members actually see gene editing and GM technologies as similar. A methodologically innovative study by Debucquet et al. (2020) in France used a free-sorting task to determine lay understandings of gene editing, GM, mutagenesis, and epigenetic techniques (n=45). The task deliberately avoided the use of technical terms that might polarise views. Participants tended to sort the techniques in two ways in an almost equal split. The first clustering was based on the level of what they associated with the randomness of the change, that is, whether the technique involved no modification, targeted or controlled modification, random changes due to external factors (mutagenesis), or random changes due to direct manipulation of the DNA (either using cisgenic or transgenic GM). The second clustering was based on the amount of exogenous DNA involved in the manipulation. In this group, conventional cis/transgenesis and SDN-3-mediated cis/transgenesis were grouped together, as were conventional mutagenesis (which involves random changes) and site-directed changes using NBTs. Debucquet et al.'s findings are discussed in more detail below.

1.3.2. Attitudes and factors influencing attitudes

Based on international studies, attitudes toward gene editing generally appear positive, and more positive than attitudes toward GM (Gatica-Arias et al. 2019; Kato-Nitta et al. 2019; Ferrari et al. 2020; Vasquez Arreaga 2020). Yang and Hobbs (2020b), drawing on a survey of 697 Canadians, found higher levels of acceptability of gene editing than transgenesis or mutagenesis. In their survey of Costa Ricans, Gatica-Arias found that they were very positive about gene editing, with 80.2% to 84.5% of participants reporting they would accept the use of gene editing for a variety of purposes. High proportions of people also believed CRISPR foods would increase crop production in the country (66%), improve the economy (63.7%), and bring benefits to their families (60.7%) and the environment (57.4%). Similarly, nearly half of the interviewees perceived low or no risk to quality of life, health, or the environment. Recent research conducted in Canada (Vasquez Arreaga 2020) found that participants perceived gene editing more favourably than GM, and drivers that affected perceptions included trust in the national food safety system, fear of novel food technologies or what was called 'food technology neophobia,' knowledge of genetics, and self-rated knowledge of gene editing. Shew et al.'s 2018 study of American, Australian, Canadian, and Belgian participants considered CRISPR to be safer than GM, but their French participants considered the technologies to be equally safe.

Attitudes to gene editing appear somewhat related to sociodemographic factors; however, these seem to have less effect than they do for GM. Some studies have found men more accepting of food produced using gene editing than women (e.g., Muringai et al. 2020). However, while Yang and Hobbs (2020a) found that men were more likely to accept GM than women, a lack of significance in the difference between the attitudes of men and women to gene editing suggests gender may have less of a role for this technology. Ferrari et al. (2020) also found no gender differences in attitudes to gene editing. No association between age and acceptability of gene editing was found by Ferrari et al. (2020) or Yunes et al. (2019).

Level of education or knowledge was not found to influence attitudes in the study by Yunes et al. (2019), but Ferrari et al. (2020) did find that those educated in a so-called 'hard science' considered gene editing more acceptable than those without such a background. Yunes et al. (2019) found that participants who grew up in agricultural environments had lower odds of considering gene editing acceptable to eliminate boar taint than those that had never been involved with agriculture; however, this was not the case for those who specifically worked within the pig production sector.

Attitudes to gene editing are heavily dependent on the application for which the technology is used. Of key interest to this study are attitudes to gene editing of food animals to improve animal welfare. In a survey of 570 participants from Southern Brazil, Yunes et al. (2019) found 56% considered gene editing to be an acceptable alternative to the castration of male pigs. However, in a second study (Yunes et al. 2021), using gene editing to produce polled (hornless) cattle was considered to be acceptable by 33%, and improved muscle growth by only 12%. Although the acceptability of gene editing in livestock production was increased by perceptions of animal welfare benefits, it was reduced when the perceptions of risks and benefits were unevenly distributed between animals, producers, the community, and industry. Although people do consider benefits when assessing food produced using gene technology, it has been suggested that "the benefits perceived by scientists, producers and industry stake-holders are often not valued or even clearly understood by the lay community" (Van Eenennaam and Young 2018; see also Bruce 2017), as we discuss further below.

1.3.3. Willingness-to-pay and willingness-to-consume gene edited food

Willingness-to-pay (WTP) studies comprise approximately half of the research to date that explores responses to gene editing in food. This type of research typically does not provide the necessary data to underpin public engagement strategies, as we discuss further below. Most, if not all, of the WTP studies compared products developed with gene editing with conventionally developed (unmodified) products as well as those using older GM techniques; some also compared gene-edited products with those produced using other types of novel food technologies.

Most of the WTP studies in the international context focus on plant-based foods. Interestingly, apples feature in three papers (De Marchi et al. 2019; Yang and Hobbs 2020; Marette et al. 2021). In all three studies, gene-edited varieties (or cisgenic in the case of De Marchi et al. 2019) were discounted less than varieties developed by GM, but were discounted more than conventionally developed varieties. This trend, with WTP for gene-edited foods being intermediate between conventional and GM foods, extends to processed foods as well, such as frozen French fries (Muringai et al. 2020) and rye bread (Edenbrandt et al. 2018).

Importantly, WTP studies exploring animal products show less consistent results. Kilders and Caputo (2021) found that there was a positive WTP for gene-edited milk when marketed with animal welfare benefits as a central strategy. However, a discount was required for beef steaks produced using RNAi technology (Britton and Tonsor 2019) where no trait was stated; however the discount was less than for associated with steaks produced with antibiotics.

In summary, it is clear from various WTP studies that foods produced with gene editing and related techniques are preferred over GM-produced food, but less preferred than conventional foods. This

finding is useful, but WTP cannot be taken as a simplistic proxy for acceptance or attitudes. Food choices are highly contextual. For example, country of origin appears to shift behaviours more than production technique in some studies (De Marchi et al. 2019; Edenbrandt et al. 2018).

Moreover, the preponderance of studies based on WTP, WTC, or similar metrics suggests a desire on the part of food producers to test the market before scientific investment. This strategy might be seen as a sensible business approach, but ignores the fact that asking these sorts of questions might be premature, given the levels of understanding and engagement in the community including amongst potential consumers. We contend that early stage engagement and deliberation about uses of these techniques and how they are best communicated to the community is prudent and the most effective approach, and hence was undertaken in the current study.

1.4. Communication and engagement about gene editing in food and livestock

Although several researchers (e.g., Tizard et al. 2019) have recognised the importance of community engagement in relation to public acceptance of the use of gene editing, and approaches have been suggested, there has been little attention to approaches that draw on an understanding of community attitudes derived from empirical investigation within the literature. It is clear from the literature summarised above that attitudes are generally more positive toward gene editing than GM, despite lower levels of knowledge. It appears that certain aspects of gene editing (such as it being perceived as 'less random' and 'less foreign') as compared with GM are driving these attitudes. However as noted previously, it is unclear whether these attitudes are a result of research participants being given this information, or whether community members would perceive these differences when unprompted and view them as the most important considerations relating to gene editing. For instance, it is less clear whether gene editing would be seen as less risky than GM because of these differences. This point is critical when evaluating the available research literature: the idea that gene editing might be found more acceptable because the technology differs from GM appears to be embedded within the framing of much of the current research and hence findings about positive attitudes may not be well-founded. The proposed application of gene technology, and the context in which the application sits, both clearly matter to community members, and hence these factors may be important for both public engagement and regulation. Although some sociodemographic factors appear to be related to attitudes, more work is also required on these issues.

What follows is a summary of some additional findings from the research literature that relate to community engagement, specifically related to potential sources of information about gene technology. In addition, we summarise approaches drawn from different fields that have been used when communicating about complex issues that have science at the core, and discuss their advantages and disadvantages. The information presented here has been used in the development of the engagement strategy presented in Section 9.

1.4.1. Sources of information

The internet is the main medium through which the community obtains information about gene technology (including both GM and gene editing) in Australia (Cormick and Mercer 2019), followed by TV documentaries, TV news stories, and TV current affairs shows. Interestingly, TV documentaries are considered the most trustworthy, even though they are not the most popular medium.

Scientific organisations, specifically the CSIRO and the National Health and Medical Research Council, are considered the most trusted sources of information about gene technology (Cormick and Mercer 2019) The food regulator Food Standards Australia New Zealand (FSANZ) is a close third. Those organisations considered trustworthy by the least number of participants were industry groups and overseas regulators (19%). However, it is worth noting that Cormick and Mercer's focus included

medical applications of gene technology, and that different types of expertise may be considered important when talking about gene technology in food and livestock production. Farmers are considered the most trusted actors in the Australian food system (Henderson et al. 2011), in which Australians have very high levels of trust. Hence in the absence of any prior studies, it is important to explore which actors are trusted sources of information about gene editing in livestock production.

1.4.2. Pros and cons of commonly used approaches

Transparency

There has been interest in transparency as a way for agricultural industries to maintain their SLO in recent years. Some have advocated that it is a way to demonstrate openness and a willingness to share information and that that alone engenders trust and will maintain an organisation's SLO. In addition, transparency may allow the community to know more and gather more evidence about what is occurring, and then ultimately place trust in organisations who appear transparent based on facts. However, as Garsten and Jacobsson (2011) note, this same sort of transparency can raise further questions or allow points of debate to become visible, ultimately resulting in a sense of insecurity and mistrust. Although transparency is important for accountability because it allows society to 'witness' industry practices (Barry 2013), this would only allow for concerns to be raised retrospectively and would not protect an organisation's SLO. In addition, providing information about activities does not ensure that these activities would be found acceptable by the community.

Awareness raising and increasing knowledge

Most science communication activities in Australia are aimed at raising awareness about science and technology (Metcalfe 2019). However, while it is important for people to become aware of issues so that they can engage with them, it is important to note that information is not neutral, and how information is framed can influence attitudes. In addition, the evidence about whether increasing knowledge about gene technology leads to increased acceptance of gene technology is conflicting and highly contextual. There is evidence that increasing knowledge can also lead to negative perceptions and so-called 'boomerang effects' (e.g., see Hart and Nisbet 2012; Trevors et al. 2016). Finally, increasing knowledge does not necessarily lead to changes in behaviours.

Persuasion

Persuasive communication approaches are used in public health campaigns and draw on a range of types of appeals, such as to fear or empathy (Heffner et al. 2021). These approaches may also draw on behavioural science insights in order to understand how to motivate people toward a particular outcome (e.g., Bonell et al. 2020). However, these types of approaches may undermine community engagement and an organisation's SLO if the organisation appears to be working toward a particular outcome rather than being interested in and open to consultation and engagement.

Trust/trustworthiness

Trust has also been an area of interest to agricultural organisations, although it is not strictly an approach to communication and engagement, but rather a concept that should underpin it. Importantly, trust is a way of managing complexity and helps us to solve problems when information is uncertain or unavailable. Institutional trust (in companies or organisations) relies on them being trustworthy (O'Neill 2018), which in turn relies on individuals within them and organisations as a whole being competent (having the ability to complete the task) and reliable (having completed the task regularly in the past). Thus trustworthiness is dependent on the particular task that an organisation or individual is being asked to do. In the context of this study, ensuring the welfare of animals and producing affordable meat, for instance, may be considered by community members as

different tasks which result in different levels of trust in various actors, including the industry as a whole.

Risk communication

Risk communication is a distinct subfield and practitioners of risk analysis have their own norms for communication (Balog-Way et al. 2020). Risk communication research has tended to focus on *messengers* (the individuals and organisations purposefully engaging in the communications), *message attributes* (the qualities and the characteristics of the communication), and *audiences* (the intended message recipients) (Rickard 2019; Balog-Way et al. 2020) as important separate categories when considering the development of engagement programs. However, using a risk communication frame and approach assumes that there is already potential for public perception of risk, as well as an actual risk associated with an action, and does not allow for engagement about whether the action should take place at all. Hence, although risk communication may be important when communicating about events such as pandemics so that people can assess the risk of their actions (or inactions), it does not allow for the type of upstream engagement processes required for maintaining SLO.

Values-based communication

The concept of values-based communication is based on the idea that audiences are more likely to accept information from someone who they perceive has similar values and cares about similar things to them (Cormick 2019). Cormick (2019) suggests that when values are in alignment (assessed via a tool such as a values prism), information-based strategies such as those aiming to increase awareness and knowledge may be successful. However, as the gap in alignment widens, strategies that involve more deliberation and discussion are required. If values are not in alignment, then engagement will need to use framing and other strategies to create alignment between the communication and audience values.

1.4.3. Summary

There are several approaches to communication that are commonly used when aiming to engage the community on issues that have science at their core. The evidence base for what works is scant, and many engagement strategies in practice borrow aspects from all of the approaches identified above. Effective strategies are highly contextual and there is no one-size-fits all approach. Common amongst these approaches is a need to understand the audience, their values, and their perceptions of the issue as well as their perceptions of the various actors involved as these factors dictate which approaches and tactics are likely to be most effective.

2. Objectives

This project used qualitative and quantitative research methods to explore and understand current Australian public knowledge and attitudes toward gene editing and its use in production animals, particularly sheep and cattle. Results from the project will help to inform MLA's future investment in gene editing research and its applications, and shape an appropriate public engagement program that will facilitate more nuanced formation of public opinion and public policy about the use of gene editing and other novel technologies in agriculture such as nanotechnology.

The specific aims of this project were:

1. to explore the knowledge and values that Australians hold about practices and policies relating to gene editing in livestock;

2. to analyse the influences and drivers of public attitudes and values about gene editing, including on what perceptions, experiences, and evidence (scientific or otherwise) these attitudes and values are based; and

3. to establish best practice methods for articulating and addressing conflicts in the context of a community engagement program designed to improve transparency and levels of public trust, with regard both to gene editing and more generally to technology use in livestock production.

Our combination of methodologies and analysis of our data against the backdrop of available literature permitted us to successfully meet these aims as summarised below.

3. Methodology for Community Attitudes Research

This report presents key findings of a research project examining Australian community and producer attitudes toward the prospective use of gene editing in beef and sheepmeat production. The community research aimed to gain a rich understanding of the diversity of existing views within the Australian community, provide insights into the drivers of community views, and identify ways in which MLA can engage members of the community about this topic. To do so, we collected data through several methods, including two preliminary and two confirmatory focus groups, and a community survey. Robust panel recruitment methods were utilised for the community research to ensure a mix of demographic characteristics as well as diverse views amongst participants. Since this study was associated with community and not just consumer views, we included a small number of non-meat consumers including vegetarians and vegans in the study.

3.1. Identifying community discourses on gene editing in livestock production

Our approach to analysing community attitudes toward the prospective use of gene editing in livestock production was informed by Q-methodology, which is a research technique used in social sciences which is designed to capture and compare the subjective or first-person viewpoints of research participants (Watts and Stenner 2005). Q-methodology combines quantitative and qualitative techniques to establish the existence of different views and to compare these views with both depth and rigour (Brown 1980). The name 'Q' comes from the type of factor analysis that is used in Q-studies. Q-factor analysis takes people as its variables in order to identify shared and different ways in which a particular group of people think and feel about an issue of interest. Q-factor analysis thereby reduces many individual viewpoints to a small number of factors, which we interpret as societal discourses (Watts and Stenner 2005), that is, as the ways in which a group of people understand, interpret, and communicate about a topic (Dryzek 2013). Study participants may be found through analysis to be significantly associated with one or more of these discourses.

A study using Q-methodology typically involves at least three steps, the first of which is a preliminary stage in which a set of opinion statements are generated which are representative of the opinions about the topic within the study population. Typically, between 40 to 80 carefully selected statements make up the Q-sample (Watts and Stenner 2012). These statements are used to design a particular type of quantitative survey, known as a Q-sort (see Box 2). In the second step, research participants complete the Q-sort, typically as part of an interview or focus group that simultaneously collects qualitative information about participants' views. Finally, the Q-sorts are analysed using Q-factor analysis and interpreted with the help of the accompanying qualitative data. If successful, this process results in a set of distinct factors, which indicate study participants who have ranked the opinion statements in similar ways in the Q-sort (Brown 1980). These factors describe the shared and diverging views within the sample population and can be interpreted as distinct discourses on the topic. The primary aim of Q-methodology is not to answer questions about the prevalence of the identified discourses, or to identify the distribution of discourses across particular social groups (Brown 1980). However, once the discourses within the population have been characterised, their distribution can be analysed using established survey methods (Talbott 1963; Baker 2010), if desired.

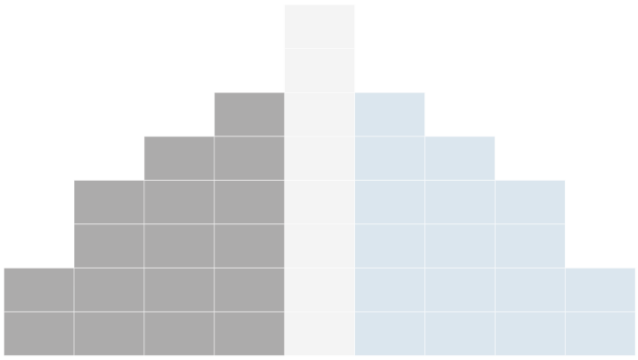
Following a Q-methodology approach, we first generated a wide range of opinion statements about gene editing in red meat production based on comments made by participants in two preliminary online focus groups. A review of existing literature on community attitudes toward gene editing in

food production was also conducted to ensure that no relevant opinions were omitted. The preliminary focus group respondents were prompted through structured and facilitated discussion to discuss their views on gene editing technology, its various prospective applications in beef and sheepmeat production, and the social and regulatory environment in which gene editing in beef and sheepmeat production might be applied.

Box 2: What is a Q-sort?

The data for Q-factor analysis come from a sorting and ranking exercise, known as a Q-sort. During the Q-sort, each research participant sorts a set of carefully selected statements into a quasi-normal distribution (see Figure 2 below) so that the relative position of each item is meaningful to the participant (Watts and Stenner, 2012). The sorting distribution is constrained to encourage participants to reflect on the nuances of their opinions. Typically, the positions of the statements reflect the degree to which a participant agrees or disagrees with the sentiment expressed by the statement. The items used in this sorting exercise should be broadly representative of the existing views within the target population, as this allows each participant to feel that they can fully express their viewpoint through the Q-sort (Paige and Morin, 2016).

Figure 2: Distribution of Statements
Participants sort each statement into one of the boxes, from 'strongly disagree' (left) to 'strongly agree' (right)



Transcripts from the preliminary focus groups were thematically coded to identify key themes and opinion statements were identified for each theme. This analysis yielded 530 statements, which were refined, combined, and revised to create a workable set that the community research participants could comfortably sort into the Q-sort matrix, while still retaining the distinctive sentiments identified in the thematic analysis. A preliminary set of 52 statements were selected, which were piloted with colleagues at the University of Adelaide, as well as by 16 recruited pilot participants. Based on feedback from pilot participants, edits were made to some statements to improve clarity and remove similar statements. The final Q-set consisted of the 42 items listed in Table 3, Section 4.2.

The Q-sorts were carried out using a commercial web-based application, QMethod Software (Lutfallah and Buchanan 2019; www.qmethodsoftware.com). Before conducting the Q-sort, participants watched a brief video introducing gene editing and an instructional video about the survey method. After watching the videos, participants were asked to read the statements in the Q-set and each sorted them into one of three piles, depending on whether they were similar to their thinking, dissimilar to their thinking, or neither similar nor dissimilar to their thinking. Once all of the statements were sorted into one of these piles, participants could move on to the Q-sort, where they were asked to sort the statements onto a matrix with a quasi-normal distribution and scale from most dissimilar to their

thinking to most similar to my thinking. A certain number of statements could be given each rank, according to the frequencies shown in Table 1. After completing the Q-sort, participants were asked to provide written responses about why they ranked the statements the way they did.

Table 1: Q-sort distribution used in the study of community attitudes toward the use of gene editing in beef and sheepmeat production

	Most dissimilar to my thinking								*Most similar to my thinking*
Rank	-4	-3	-2	-1	0	+1	+2	+3	+4
Frequency	2	4	5	6	8	6	5	4	2

Study participants completed the Q-sort as part of confirmatory focus groups (see Box 3), each of which was held over a three-day period in March 2021 on a private web platform established for the purpose of the focus groups. The Q-sort data was linked by an ID code to their qualitative focus group responses to aid in the interpretation of the identified factors. Transcripts of the online discussions were generated, and each response was manually coded using methods similar to open coding (Strauss and Corbin 1990). Qualitative responses were analysed using the generic inductive qualitative model (Hood 2007; Maxwell 2012), which blends the process with description and interpretation during the generation of research questions.

Box 3: What are asynchronous online focus groups?

Online focus groups involve "a selected group of individuals who have volunteered to participate in a moderated, structured, online discussion in order to explore a particular topic for the purpose of research" (Peacock et al. 2009 p.119). Online focus groups are particularly beneficial for including hard to reach populations or other situations where face-to-face meetings are difficult (Williams et al. 2012), such as during the ongoing COVID-19 pandemic.

Asynchronous focus groups allow researchers and participants to read and respond to questions and comments at times most convenient to them, using online discussion boards or forums (Williams et al. 2012). Participants can log on to the forum at any time of day and do not need to be online at the same time. Asynchronous focus groups may be held over the course of several days, with new discussion topics or tasks displayed each day on separate pages.

Q-factor analysis was conducted on the collected Q-sorts, using the built-in statistical analysis package in the QMethod Software application. Five factors were extracted through Principal Components Analysis (PCA) and rotated using Varimax rotation. In total, these factors explained a combined 51% of the total study variance. Further information on factor analysis and extraction is detailed in Table 5 in Appendix A. As part of the analysis, a single, idealised Q-sort is generated for each of the extracted factors, which represents the viewpoint of that factor (Watts and Stenner 2012). These representative Q-sorts aid in the interpretation of the factors and are used to illustrate the results of the Q-sorts in Section 4.2.

Interpretation of the extracted factors is an iterative process, which incorporates both the quantitative results and associated qualitative data. The qualitative data that informed factor interpretation included individual comments made by participants in the preliminary and confirmatory focus groups. The topics covered in these focus groups included attitudes toward gene editing technology in general and specific applications of gene editing in beef and sheepmeat productions.

The prevalence and distribution of the identified discourses was assessed using the mean values obtained on an online community survey which was conducted in June 2021. Brief narrative descriptions of each discourse were developed, and respondents were asked to mark the extent to which each discourse aligned with their thinking about the use of gene editing in beef and sheepmeat production using a nine-point Likert type scale (1 = completely disagree through to 9 = completely agree). The community survey, including brief discourse descriptions, can be found in Appendix B. Additionally, respondents were asked to rate their level of agreement with a subset of ten opinion statements selected from the original Q-sort. Two statements were selected to benchmark each discourse, based on being both distinctive for and salient to that discourse (Baker 2010). The order in which the narrative descriptions and opinion statements were displayed in the community survey was randomised to avoid order bias. For each respondent, z-scores were calculated for each discourse and all respondents were assigned to the discourses for which their z-scores were greater than 1. Respondents could be associated with one, two, or multiple discourses, or be unassigned if none of their z-scores was greater than 1.

3.2. Investigating additional attitudes toward specific types and applications of gene editing in livestock production

A number of prospective applications of gene editing are currently being researched for use in beef and sheepmeat production. Some prominent potential applications include edits to the myostatin gene to increase muscle mass and development in cattle and sheep (Tait-Burkard 2018), the introduction of hornlessness in cattle (Rothammer et al. 2014), the improvement of disease resistance in livestock (Gao et al. 2017), and sex manipulation to alter male birth rate and therefore increase the amount of meat produced per animal as males tend to have more body mass. We selected a series of applications of gene editing to investigate based on our literature review about the current status of the application's development. Our main focus was on applications for which the scientific background research is fairly well-developed and which are likely to have potential for commercial deployment in Australia in the near to medium future. In addition, we made our final selections of applications based on the goal of representing applications with a contrasting range of aims including animal welfare and health, environmental benefits, and productivity gains (Ishii 2017). These applications of gene editing were investigated in the preliminary focus groups and the community survey using Likert-type questions, as well as the producer interviews and survey to be discussed in Section 5. Qualitative data about community attitudes to different gene editing applications were elicited during the confirmatory focus groups in response to a set of descriptive scenarios. The focus group script, including brief descriptive scenarios, can be found in Appendix C.

The application of gene editing in beef and sheepmeat production could involve several processes that might be more or less acceptable to members of the Australian community, including switching on or switching off existing genes within an animal, or introducing genetic information from the same or different species. Additionally, these alterations may or may not be inherited by future generations. A recent survey by the Office of the Gene Technology Regulator (Cormick and Mercer 2019) investigated community attitudes toward these different types of modification in the context of genetically-modified plants. To allow comparison of our findings with the results of the OGTR 2019 study, we asked community survey respondents (as well as producers) to indicate the extent to which it is acceptable to make such types of alterations to the genes of cattle and sheep.

3.3. Identifying drivers of community attitudes toward gene editing in beef and sheepmeat production

Data were collected on community research participants' awareness of gene editing, overarching attitudes toward science and technology, and views on the Australian livestock industry. Quantitative measures of community and producer attitudes were collected during the preliminary and confirmatory community focus groups and the community survey (as well as within the producer interviews and survey) as detailed in Table 2. Related qualitative responses were also collected and analysed thematically.

The effect of these variables on community members' attitudes toward the use of gene editing in beef and sheepmeat production was gauged, first by comparing the responses across each of the identified discourses, and second by analysing correlations between these statement ratings and community attitudes toward the surveyed applications and types of gene editing (see Section 4.7) in beef and sheepmeat production.

Table 2: Description of variables used to measure awareness of and pre-existing attitudes toward gene editing

Variable	Description
Awareness of gene editing	Self-rated awareness of gene editing, using the following categories: - Never heard of - Have heard of, but know little or nothing about - Know enough about it that I could explain it to a friend - Can't say/don't know (Drawn from Cormick and Mercer 2019)
Views on the Australian livestock industry	On a scale of 0–7, where 0 means completely disagree and 7 means completely agree, participants rated their level of agreement with the following statements: - People have a right to eat meat. - Australian beef, lamb, and mutton producers deserve better prices and purchase conditions. - Long-distance transport of live cattle and sheep for meat production should continue. - The standard of animal welfare on Australian farms needs to be improved. - Increased regulation of the treatment of cattle and sheep used for meat production is needed. - The welfare of cattle and sheep kept on feedlots is lower than that of free-range cattle and sheep. - It is wrong to raise cattle and sheep for meat production. (Statements were adapted from Coleman 2016 and Cormick and Mercer 2019)
Views on science and technology	On a scale of 0–10, where 0 means strongly disagree and 10 means strongly agree, participants rated their level of agreement with the following statements: - Scientists have too much control over nature. - Science and technology can solve most problems faced by human beings. - Science and technology are continuously improving our quality of life. - It is important for governments to regulate new technologies. - Science and technology are out of control, and beyond the control of governments. (Statements were adapted from Critchley et al. 2019 and Cormick and Mercer 2019)

3.4. Developing a community engagement strategy

As noted previously, SLO requires ongoing communication between stakeholders. Thus understanding factors that influence communication is vital in order to develop effective community engagement strategies. These involve identifying message attributes such as the qualities and characteristics of the communication (*how* to communicate and *what* to communicate about), messengers (i.e., *who* should communicate in terms of both organisations and types of individuals), and audiences and their characteristics (i.e., community views, perceptions, and values related to the technology and its broader context) (Rickards 2019; Balog-Way et al. 2020). Hence this research examined these factors as outlined below. The discourses identified via the Q-sorts also underpin the community engagement strategy provided in Section 7.

3.4.1. Assessment of messenger effect

As noted in Section 1.3.1, different actors involved with the development and deployment of gene editing in livestock production may have different levels of community trust with regard to communicating about gene editing including impacts on animal welfare.

In collaboration with Inspograph, the research team created a brief, animated video (see Box 4) which was primarily intended to aid discussion by providing a baseline of knowledge about gene editing among respondents. However, this video was also modified to have two alternative versions to assess the effect of different messengers on viewers' perceptions of the information provided, as well as perceptions of the goals of gene editing in beef and sheepmeat production and their overall support for the use of gene editing. To do so, a message about the aims of using gene editing in beef and sheepmeat production was appended to the original animated sequence. This message was presented by an actor portraying a farmer in one version and a scientist in the other version. The content of the message was identical in both videos.

Box 4: To view the animated video on gene editing, scan the QR code below

SCAN FOR VIDEO

Participants in the confirmatory focus groups were randomly assigned to one of the two video treatments, which they watched as one of their tasks for the first day of the focus groups. Additionally, the re-recruited preliminary focus group participants who independently completed the Q-sort were also randomly assigned to a video treatment. After watching the assigned video, participants were asked to rate their level of support for the use of gene editing in Australian beef and sheepmeat production, using an eleven-point Likert-type scale, and to indicate how they believed gene editing would affect our way of life in the future (after Cormick and Mercer 2019)

At the end of Day 1, participants were also asked to rate the extent to which they thought the video to was credible or uncredible and biased or unbiased, and to indicate what they think the main goals of gene editing are for researchers, individual producers, and the Australian beef and sheepmeat industry. We then explored the effect of the video treatments on these post-video responses.

To do so, we conducted a categorical regression that included the respondents' views on Australian livestock production and on science and technology (see Table 2) as pre-video responses and the video treatment as explanatory variables. The pre-video responses were included to account for any pre-existing attitudes that could be factored out of the model to concentrate on the video treatment effect. After accounting for these pre-existing attitudes, we explored whether there were any differences in the post-video responses between the two treatments. For a detailed description of this process, see the summary in Appendix D.

3.5. Effects of COVID-19 on the research methods

The research methods for this study were impacted by the ongoing COVID-19 pandemic in Australia. Because both researcher and participants were largely unable to meet face-to-face consistently during 2020–21, all data collection was conducted online or by telephone. Although this required our methods to be adapted to an online environment, this pivot did not impact our abilities to meet the project aims. The ability to recruit demographically diverse community participants, especially those from a variety of geographic locations, was in fact enhanced by using an online research format, and does not appear to have inhibited participation particularly given the relatively high rates of internet access and usage among Australians. However, we do suspect that changes to the timing of the data collection as a result of the need to shift to online data collection did impact our abilities to recruit producers to the study, as it overlapped more with busy periods in the agricultural schedule than was originally planned, resulting in a relatively small sample size.

4. Results for Community Attitudes Research

4.1. Sample characteristics

The following sections provide an overview of key characteristics of community research participants for each of the data collection methods.

4.1.1. Participants in the preliminary and confirmatory focus groups

At the outset of the research project, two three-day asynchronous online focus groups were conducted with members of the Australian community. In March 2021, we conducted a further two confirmatory focus groups with members of the Australian community. Each focus group consisted of between 20 and 40 participants, who were recruited by a professional recruitment company to ensure that the participants would be broadly representative of the Australian population in terms of age, gender, location, education, and dietary preference (see Figures 41–46 in Appendix E). In total, 60 participants completed the preliminary focus groups, and 62 participants completed the confirmatory focus groups. An additional nine participants partially completed the confirmatory focus groups, including the Q-sort task and tasks related to the video treatment. In addition to the participants, the focus group was moderated by three to five members of the research team, with at least one moderator present on the focus group board at all times.

The sample of preliminary focus group participants was somewhat skewed toward female (n=34) compared with male participants (n=26) due to a higher drop-out rate of male participants over the course of the three-day focus groups (see Figure 3). Gender was well balanced in the confirmatory focus groups. The greatest proportion of focus group participants in both the preliminary and confirmatory focus groups reported that they lived in suburban areas (n=30 for preliminary, and n=33 for confirmatory focus groups). However, a small number of participants from rural areas were included in both sets of focus groups.

Although the majority of focus group participants were omnivores, non-meat eaters were included in the sample for both the preliminary and confirmatory focus groups, as shown in Figure 4.

Figure 3: Number of male and female participants in the preliminary focus groups (left, n=60) and confirmatory focus groups (right, n=62) by each age category

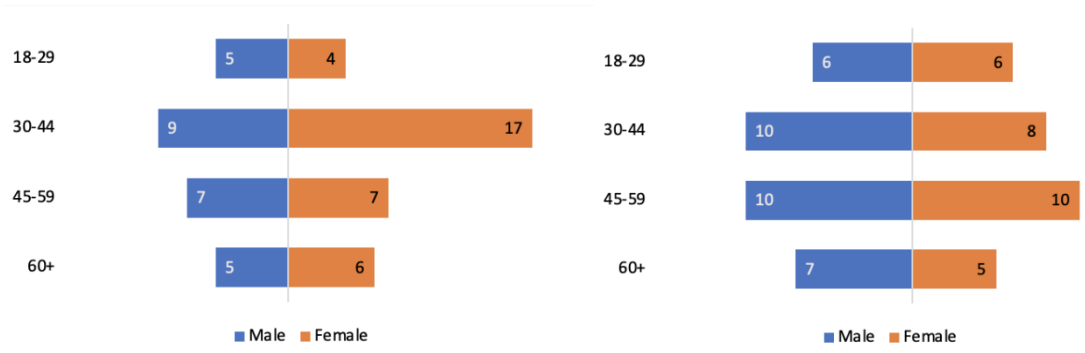
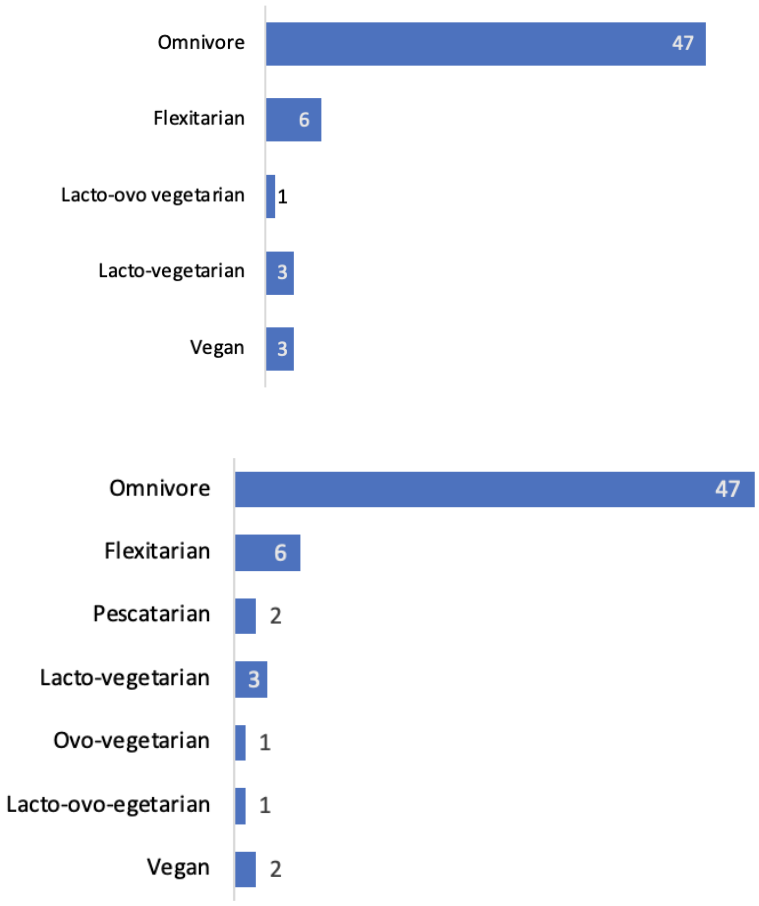


Figure 4: Number of participants in the preliminary focus groups (top, n=60) and confirmatory focus groups (bottom, n=62) by their preferred diet



4.1.2. Participants in the Q-sorts and video treatments

The participants in the Q-sorts and the video treatments were drawn from the preliminary and confirmatory focus groups. The Q-sort was included as a task in the confirmatory focus groups, while participants from the preliminary focus groups were invited to complete Q-sorts independently. In total, 100 Q-sorts were completed, of which 30 came from re-recruited participants from the preliminary focus groups and 70 were from the confirmatory focus group (including some participants who did not complete the focus groups). Two Q-sorts were excluded from the analyses due to participants expressing insufficient understanding of the task, meaning that 98 Q-sorts were eventually included in the Q-factor analysis. Because Q-methodology aims to produce generalisable discourses, rather than to make generalisable statements about the prevalence and distribution of those views, and because the sample was drawn from the previously described focus groups, further information about the Q-sort sample is not included in this report.

In total, 102 participants from the preliminary and confirmatory focus groups were included in the video treatment. These were randomly assigned to watch one of two versions of the video, as detailed above, either the scientist (n=53) or farmer (n=49) ending. Details of the two groups are included in Table 6 in Appendix E. Despite random allocation to the treatment, the scientist treatment group included a considerably larger percentage of participants between the ages of 18 and 44, while the farmer treatment group included a higher percentage of participants 45 years old or above.

4.1.3. Participants in the community survey

A community survey was distributed online in June 2021. Respondents were recruited from a research panel and managed by a professional recruitment company. In total, 2146 respondents completed the community survey. The demographic was representative of the Australian population based on Australian Bureau of Statistics categories for age and gender, education, and national and statewide populations (see Figures 5–7).

Figure 5: Percentage of male and female survey respondents in each age category (percentage of n=2146)

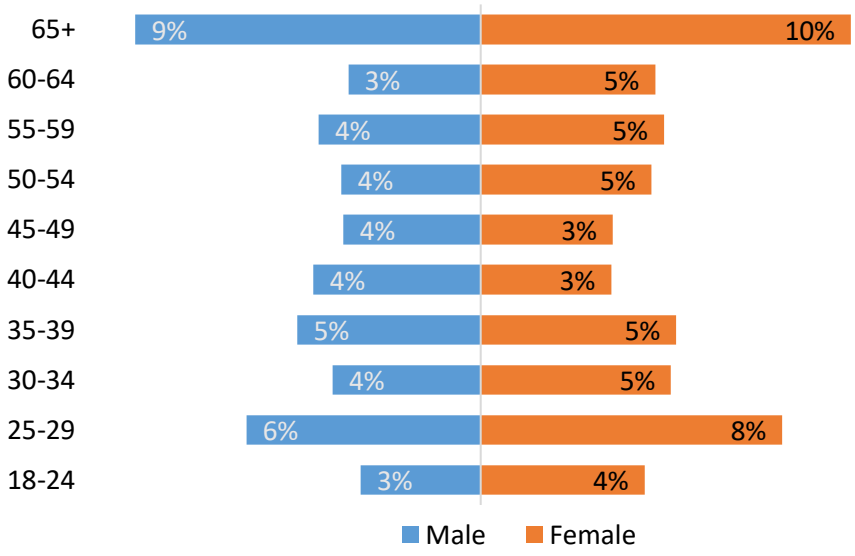


Figure 6: Highest level of attained education among survey respondents (percentage of n=2146)

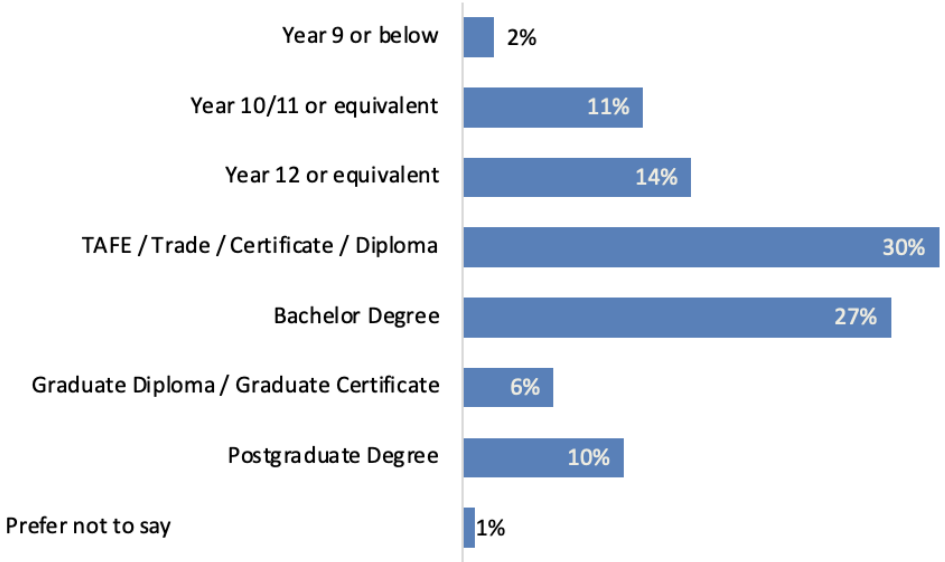
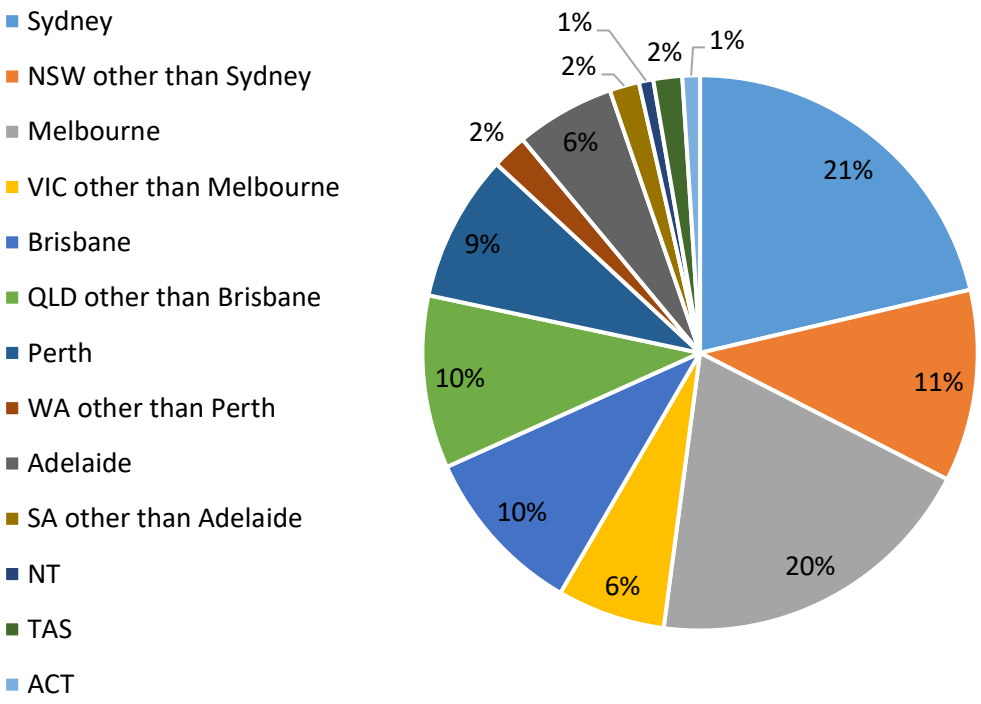
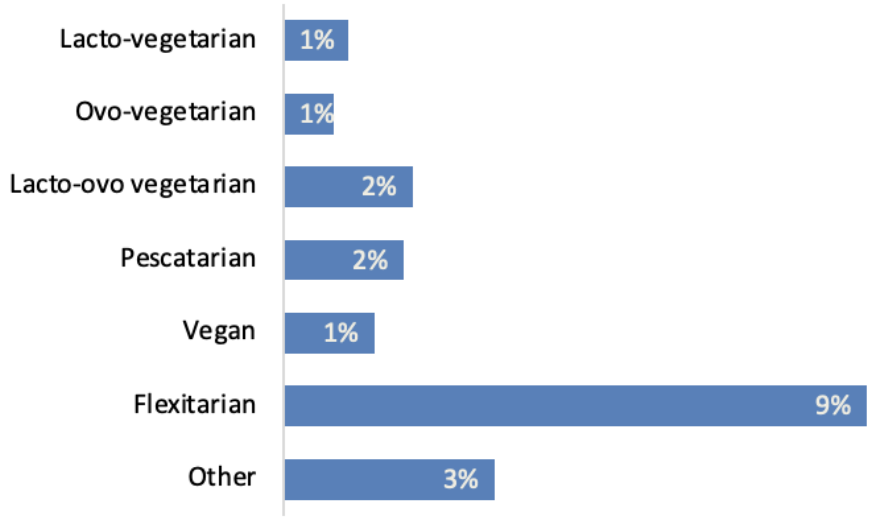


Figure 7: Residential location of survey respondents (percentage of n=2146)



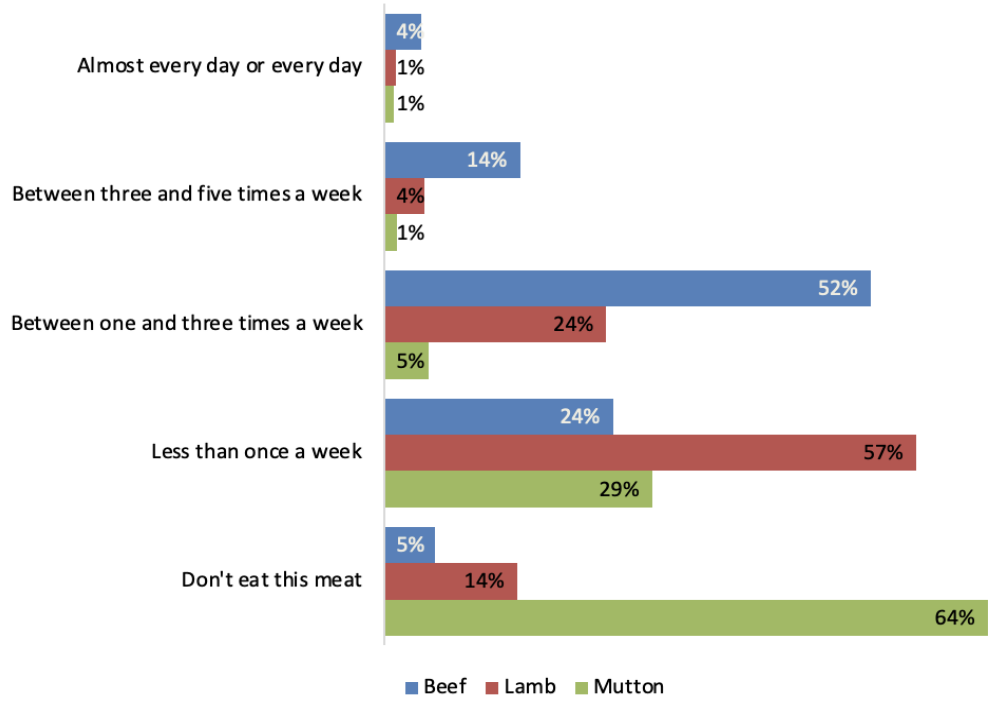
In the community survey, 80% of participants were omnivores, while 9% identified as flexitarians and 2% as pescatarians. The representation of vegetarians and vegans (7%) within the survey sample was low relative to a recent national estimate of 11% (Malek et al. 2019). The remaining 3% identified with other diets, including medically prescribed or weight-loss diets (see Figure 8).

Figure 8: Percentage of survey respondents following deliberate diets (percent of n=2146)



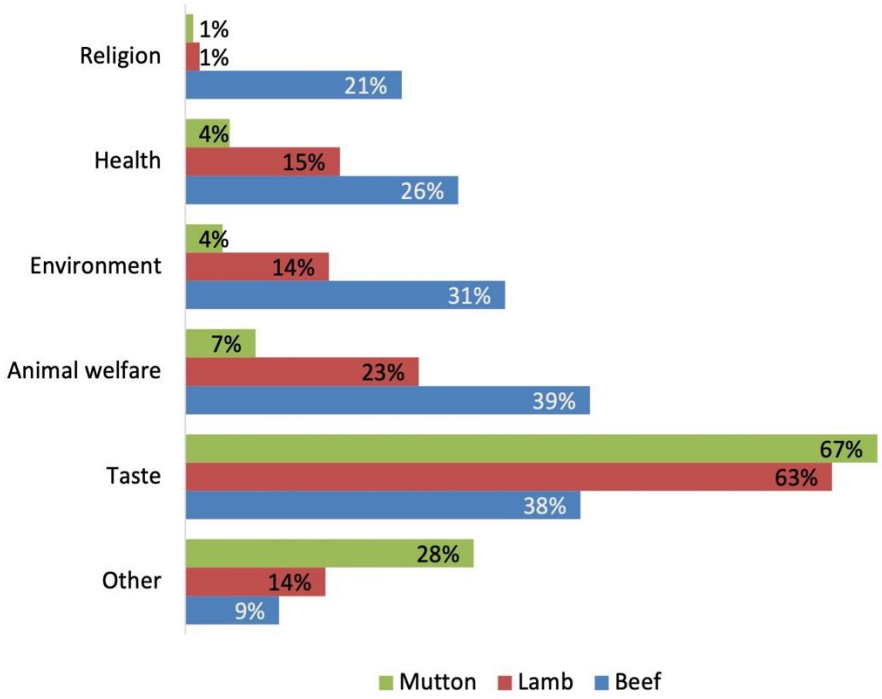
Of participants who did eat red meat (omnivores and flexitarians), over half consumed beef between one to three times per week, and lamb less than once per week (see Figure 9). Over 60% of survey respondents who did eat meat did not consume mutton.

Figure 9: Frequency of beef, sheep, and mutton consumption (percentage of n=2032, excludes 6% who do not consume meat)



The main reasons for not eating beef were animal welfare concerns (39%), dislike of the taste (38%), and concerns for the environment (31%) (see Figure 10). For lamb and mutton, dislike of the taste was the main reason not to consume meat (both over 60%).

Figure 10: Reasons for not consuming beef (percentage of n=110), lamb (percentage of n=228), and mutton (percentage of n=1306)



4.2. Community discourses on gene editing in beef and sheepmeat production

The following section summarises our findings related to community attitudes toward the prospective use of gene editing in beef and sheepmeat production. In order to identify and describe the discourses that exist within the Australian community about the prospective use of gene editing in beef and sheepmeat production, we asked focus group participants to complete online Q-sorts. The purpose of the Q-sorts was to identify patterns of similarities and differences in the subjective views of individuals and thereby distil these views into a smaller number of shared discourses.

Five factors were extracted by Q-factor analysis of respondents' Q-sorts. All five factors meet the commonly-used statistical requirements for factor extraction (see Table 5 in Appendix A). Together, these factors explain 51% of the variation in respondents' rankings of the 42 opinion statements in the Q-sort.

Each of these extracted factors is interpreted as a discourse, which is described below by means of a representative Q-sort and a narrative description. The representative Q-sorts summarise the findings from the Q-factor analysis by means of an idealised Q-sort for each discourse. The representative Q-sorts show the rating that would be assigned to each statement by a hypothetical participant who is 100% aligned with a particular discourse. These representative Q-sorts were developed based on the factor loadings for each statement, which can be found in Table 7, Appendix F. Table 3 shows the idealised statement rankings for each of the discourses, while Figures 11–15 visualise this information for each discourse. The narrative descriptions of the discourses were created using both the quantitative results of the Q-sort analysis and the accompanying qualitative responses. Statement rankings are included where they have made a relevant contribution to the narrative interpretation. For example, (#15, +3) indicates that statement 15 was given a ranking of +3 in the representative Q-sort.

Table 3: Ranking of statements 1–42 by each factor

The highest ranking for each statement is bolded and the lowest ranking for each statement is underlined. The Factor Array Scores for each of the factors (1–5) make up the representative Q-sort for each discourse. By reading the column for Discourse 1, we can see that Discourse 1 ranked statement 9 at -4, meaning that this discourse does not hate the thought of the whole process of gene editing. By reading the table rows, the scores for each statement can be compared across the discourses. For example, we can see that Statement 1 was ranked -2 by Factor 1, +1 by Factor 2, and so on.

Statement number	Statements	Statement ranks by discourse				
		1	2	3	4	5
1	Gene editing of cattle and sheep goes against the laws of nature.	-2	**+1**	-3	0	-2
2	Scientists don't understand the long-term effects of gene editing.	0	**+2**	-2	0	-2
3	Gene editing is okay for plants and crops (including for animal feed).	+1	-2	**+2**	0	+1
4	We should not use gene editing to insert genes from different species.	+1	**+2**	-1	0	**+2**
5	It is a problem that cattle and sheep cannot consent to gene editing.	-3	-1	0	**+3**	0
6	I am convinced that gene editing of cattle and sheep is safe.	**0**	-4	-2	-2	**0**
7	It will be difficult to modify one trait without unintentionally affecting other traits.	0	+2	+2	+2	-3
8	When scientists edit genes, they're playing God.	-2	**+2**	-4	+1	-1
9	I just hate the thought of the whole process of gene editing.	-4	0	-3	-3	**+3**
10	Gene edited beef and cattle will disrupt natural ecosystems.	-2	**+1**	-2	+1	-2
11	Gene editing is fundamentally different than selective breeding in cattle and sheep.	0	**+1**	0	-1	0
12	Gene editing should be used if the benefits to society outweigh the risks.	**+2**	-2	0	**+2**	-2
13	If gene editing helps us to meet the global demand for meat, then that's a good thing.	**+2**	-3	-3	-1	0
14	I'd support using gene editing to improve the welfare of cattle and sheep.	**+4**	-1	+1	-4	0
15	We need to use gene editing to modify cattle and sheep to be compatible with new or changing environments.	**+3**	-3	-1	+2	+2
16	Gene editing should not be used to improve the economic conditions of meat producers.	-1	0	0	-2	**+3**
17	Using gene editing to prevent diseases in sheep and cattle would be a good thing.	**+4**	0	+3	+1	-1
18	I am uncomfortable with using gene editing to control or change how cattle and sheep feel, even if this could reduce their suffering.	-2	-1	-1	-4	**+1**
19	I'd be fine with using gene editing to offset the environmental impacts of meat production.	**+1**	-2	0	0	0
20	Researchers should use gene editing to increase our understanding of cattle and sheep DNA.	**+2**	-2	+1	**+2**	-1

21	Some characteristics of cattle and sheep are fundamental and therefore shouldn't be altered.	0	+1	**+4**	-3	-3
22	Gene editing of cattle and sheep would result in less natural diversity.	0	**+1**	0	**+1**	-3
23	If gene editing could produce healthier meat, that would be fantastic!	**+3**	-1	-2	+2	-1
24	It is wrong to raise cattle and sheep for meat production.	-4	-3	+2	+3	**+4**
25	I wouldn't want meat to look or taste different as a result of gene editing.	**+2**	+1	-1	-1	-4
26	Ethics should always come before profits in meat production.	**+3**	**+3**	**+3**	+1	**+3**
27	Gene editing cattle and sheep will make something natural into something unnatural.	-3	**+3**	-2	-1	0
28	I'd support gene editing of livestock if it helps to produce more affordable meat.	**+1**	-3	-4	0	**+1**
29	I'd be happy to serve gene edited meat to my family.	**+1**	-4	**+1**	-1	-4
30	I am worried that if we accept gene editing in cattle and sheep, we will start doing it to humans next.	-1	**+4**	-1	**+4**	+2
31	Humans are too confident about their abilities to control nature: I believe that Mother Nature will show us who is boss.	0	**+3**	**+3**	-2	-1
32	Some people will always go too far to try to produce the "perfect" animal.	+1	+3	**+4**	-1	-3
33	If it is properly regulated, gene editing can be used responsibly in meat production.	**+3**	-1	+1	0	+1
34	I need to see all the facts before I decide how I feel about gene editing.	+2	**+4**	+1	+3	+1
35	When it comes to gene editing, cattle and sheep should be treated equally to humans.	-3	0	**+3**	-3	-1
36	Greater financial support for farmers would eliminate the need to genetically alter cattle and sheep.	-1	-1	-1	-2	**+2**
37	Gene editing can't solve the problems that I care about in the food system.	-2	0	0	**+4**	+3
38	The meat industry is doing fine without gene editing.	-3	0	**1**	-2	0
39	Most of the time, gene editing is just about profit.	-1	+2	0	-3	**+4**
40	Gene editing research that is funded by industry can't be trusted.	-1	0	+2	**+3**	-2
41	Gene editing should be used to produce alternatives to meat products that don't require animal agriculture.	0	-2	**+2**	+1	**+2**
42	Eating gene edited meat is going to have negative effects on human health in the long run.	-1	0	-3	0	**+1**

4.2.1. Discourse 1: Morally neutral and potentially useful

Discourse 1 is bipolar, meaning that some participants are negatively associated with the discourse and others positively associated. A Q-sort completed by a negatively-associated participant will be a mirror-image of that of a positively-associated participant (see Figure 11). This finding suggests that a similar reasoning underlies their Q-sorts, but they are nevertheless coming to opposite conclusions. Because all of the participants who are negatively associated with Discourse 1 are also positively associated with Discourse 2 at the $p<0.01$ significance level, we only describe the position of the positively-associated participants in the following discussion. However, an interpretation of the negative expression of Discourse 1 is included in Appendix F.

Discourse 1 considers gene editing as a morally-neutral tool that has great potential to address perceived problems in the Australian red meat sector (#37, -2). Hence, gene editing should be judged by its proposed applications, rather than as something that is inherently or in principle good or bad (#9, -4). Discourse 1+ does not view gene editing as a technology that presents novel ethical challenges (#5, -3) or risks (#10, -2; #27, -3) for red meat production.

Discourse 1 is concerned about what participants associated with it viewed as problems or challenges with the way in which red meat is currently produced (#38, -3) and supports the use of gene editing to address key issues. In particular, respondents who are associated with Discourse 1 support the use of gene editing to improve the health and welfare of animals in meat production (#14, +4; #17, +4), or to adapt cattle and sheep to new and changing environments (#15, +3). To a lesser extent, Discourse 1 also supports using gene editing to improve the environmental sustainability of meat production (#19, +1).

Although Discourse 1 identifies problems within Australian meat production and strongly supports higher welfare for livestock in Australia, it is not fundamentally opposed to meat production (#24, -4) or the use of gene editing to support the red meat industry. If gene editing can help the sector to meet global demands for meat (#13, +2) or make meat products healthier (#23, +3) or more affordable (#28, +1), then Discourse 1 views this as a good thing. Perhaps as a consequence, Discourse 1 is relatively disinterested in the use of gene editing to produce alternatives to meat production (#31, 0).

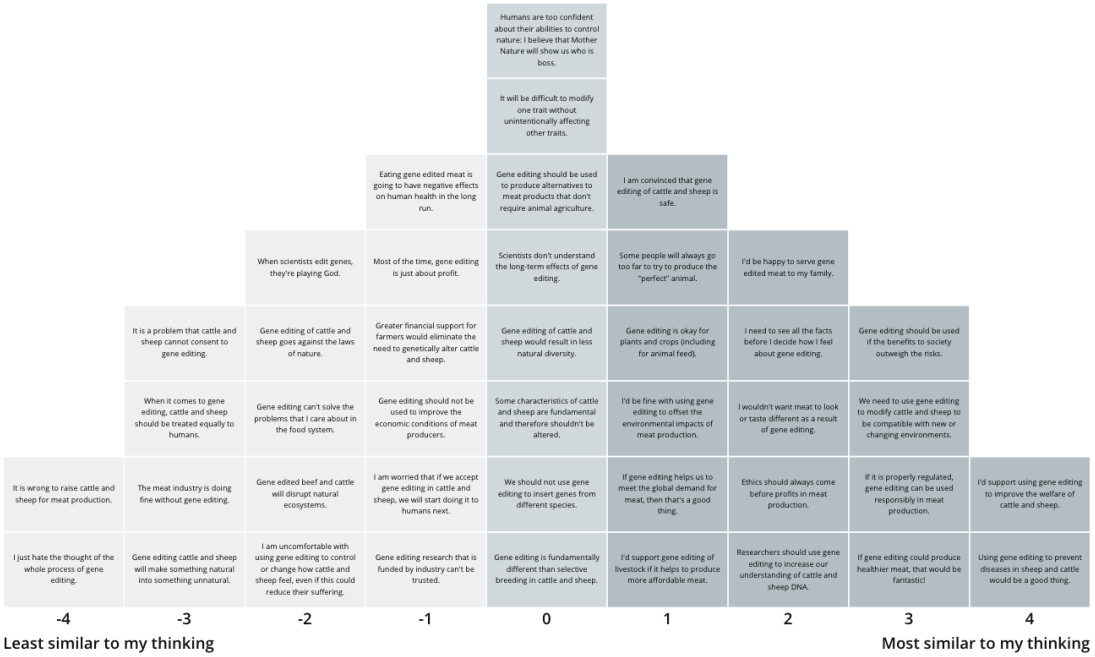
Nevertheless, qualitative responses suggest that participants associated with Discourse 1 think that gene editing should not be used solely to increase industry profits, but should benefit society, the environment, and/or the animals used in meat production. This point is illustrated by the following quote from a focus group participant whose Q-sort is associated with Discourse 1:

> *I think productivity increases are important, however I am not sure increasing muscle growth is the way to go. I think increasing productivity by making the animal less prone to conditions, pests and diseases would be of more benefit…*

People associated with this discourse support regulation and oversight of gene editing and believe that proper regulation can allow the technology to be used responsibly (S33, +3). They are relatively trusting of the science (S30, -1; S40, -1) and the technology (S6, 0). With the proper assurances with regard to safety, efficacy, and ethical oversight, they would be happy to serve gene edited meat to their family (S29, +2).

Figure 11: Representative Q-sort for Discourse 1 (positive association)

Statements that are ranked furthest to the left in the grid are those that are least similar to the views of Discourse 1, while statements that are furthest to the right are those that are most similar to the views of Discourse 1. These poles are reversed for participants who are negatively associated with Discourse 1. Statements that are near the centre of the grid are those that people associated with Discourse 1 tend to feel neutral or unsure about. Statement ranks for each discourse are also shown in Table 3.



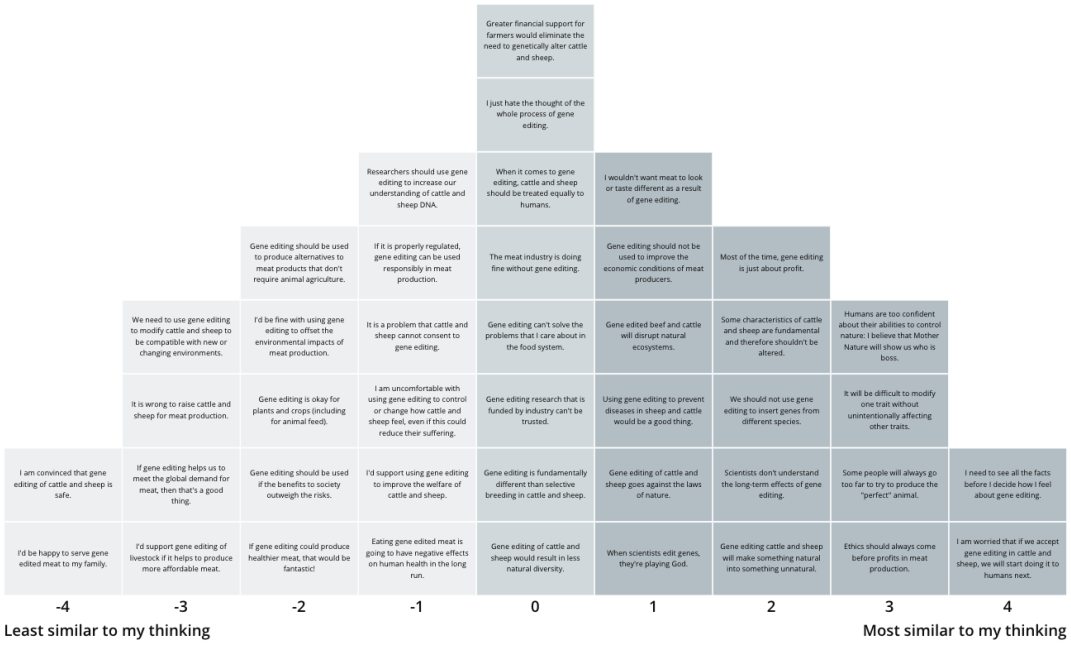
4.2.2. Discourse 2: Interfering without understanding

Discourse 2 focuses on worries about the unknown, long-term, and negative consequences that may result from the use of gene editing in beef and sheepmeat production. People associated with this discourse view gene editing as interfering with and disrupting natural systems that are complex and finely balanced (#1, +1; #27, +3). In their view, there is always a risk or what they describe as 'a price to pay' when humans alter nature, because altering one trait through gene editing is believed to have unintended consequences (#7, +2) that scientists do not fully understand (#2, +2; #8, +2; #31, +3). Importantly, Discourse 2 does not support using gene editing to increase our scientific understanding of cattle and sheep DNA (#20, -2).

Consequently, participants associated with Discourse 2 are concerned about any proposed application of gene editing in livestock or humans (#30, +4) due to the inherent risks of this novel technology (#3, -2; #13, -3; #15, -3, #19, -2; #41, -2; #20, -2). People associated with Discourse 2 view both meat and meat alternatives that have been produced via gene edited as unsafe to eat (#6, -4; #28, -3), and would not eat gene edited meat or serve it to their family (#29, -4). Notably, participants associated with Discourse 2 do not agree that gene editing should be used in meat production, even if the benefits to society outweigh the risks (#12, -2). Relatedly they also are sceptical that the perceived risks of gene editing can ever be appropriately managed (#33, -1), which suggests that the benefits of gene editing will never outweigh the perceived risks.

Figure 12: Representative Q-sort for Discourse 2

Statements that are ranked furthest to the left in the grid are those that are least similar to the views of Discourse 2, while statements that are furthest to the right are those that are most similar to the views of Discourse 2. Statements that are near the centre of the grid are those that people associated with Discourse 2 tend to feel neutral or unsure about. Statement ranks for each discourse are also shown in Table 3.



4.2.3. Discourse 3: Prioritise animal rights and welfare

Discourse 3 is distinguished by a strong concern for the rights of animals that are raised for meat production. Those aligned with Discourse 3 feel that animals should have the same rights as humans regarding the use of gene editing (#35, +3), including placing limits on the kinds of traits that can be altered in animals (#21, +4), such as their appearance or temperament.

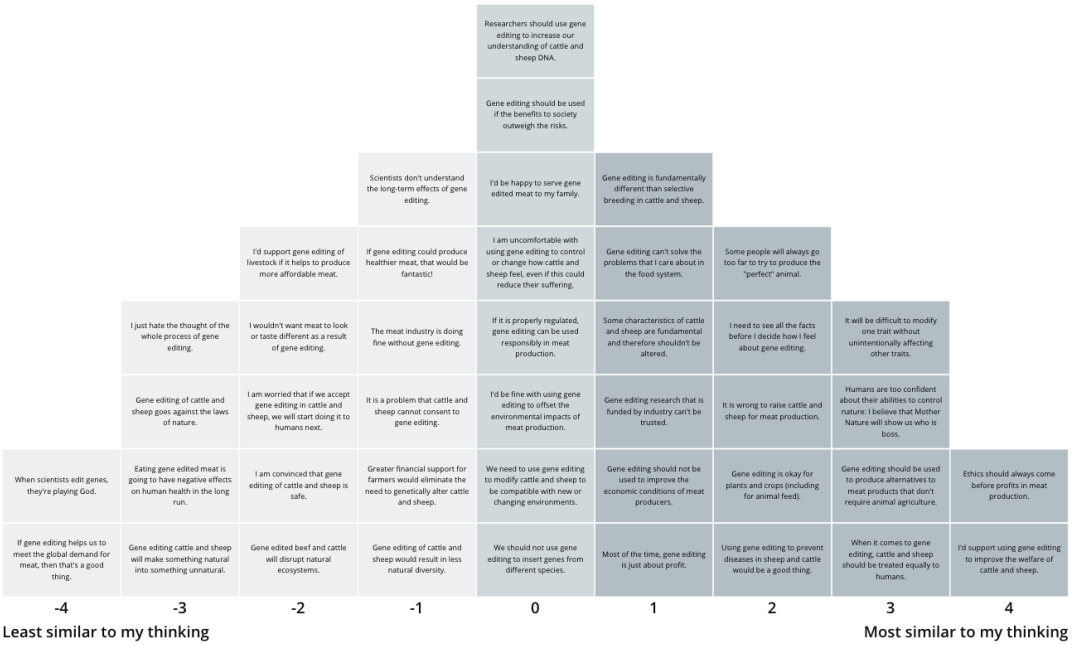
People associated with Discourse 3 are ambivalent about the use of gene editing in meat production because they think it is wrong to raise cattle and sheep for meat production (#24, 2). Consequently, they do not agree with using gene editing to meet current or future demands for meat (#13, -3) or to make meat more affordable (#28, -4). Although Discourse 3 shows tentative support for the use of gene editing to reduce stress and pain or the number of animals used in meat production (#14, +1; #17, +3), people associated with this discourse are sceptical about claims that gene editing will be used to improve animal welfare. They are mistrustful of the meat industry, as well as research funded by the meat industry (#40, +2), and believe that gene editing will be used to breed the perfect meat-producing animal (#32, +4), regardless of how this may affect animal welfare.

Discourse 3 shares some similarities with Discourse 1, in that it is relatively accepting of gene editing as a novel technology (#9, -3) and is not concerned about the possibility that gene editing might be used in humans (#30, -2) or plants (#3, +2). Discourse 3 participants also do not perceive gene editing as going against the laws of nature (#1, -3), nor do they believe that scientists who use gene editing are playing God (#8, -4). However, in contrast to both Discourse 1 and Discourse 2, people aligned

with Discourse 3 tend to be less interested in, or concerned about, the health effects of consuming gene-edited meat (#23, -2; #42, -3), possibly because they do not eat meat or serve it to their families. Discourse 3 does support the use of gene editing in plants and to produce plant-based alternatives to meat (#41, +2), which further emphasises that their reticence about gene editing in livestock is primarily related to concerns about animal rights and welfare in meat production.

Figure 13: Representative Q-sort for Discourse 3

Statements that are ranked furthest to the left in the grid are those that are least similar to the views of Discourse 3, while statements that are furthest to the right are those that are most similar to the views of Discourse 3. Statements that are near the centre of the grid are those that people associated with Discourse 3 tend to feel neutral or unsure about. Statement ranks for each discourse are also shown in Table 3.



4.2.4. Discourse 4: I just don't know

Discourse 4 captures the positions of people who are genuinely undecided about the use of gene editing in beef and sheepmeat production and are still comparing the pros and cons for the issues about which they care the most. Of the nine participants associated with Discourse 4 at the $p<0.01$ level, five participants are negatively associated, meaning that Discourse 4 is bipolar, which further underscores the undecided nature of this discourse. In other words, Discourse 4 encompasses both people who tend to believe that gene editing can help solve the problems that they care about (#37, +4), and those who believe the opposite. We therefore include two interpretations of Discourse 4, one of which represents the positively-associated views (Discourse 4+) and one of which represents the negatively-associated views (Discourse 4-).

Unlike Discourse 3, which is particularly concerned about animal welfare, Discourse 4 is not united around a single issue. Instead, key concerns include 'big picture' issues, such as environmental sustainability and global food security, but also include more personal concerns, such as the quality of meat, which might be positively or negatively impacted by gene editing. Discourse 4+ tends to prioritise the social effects of gene editing (#30, +4; #20, +2), including impacts on meat producers

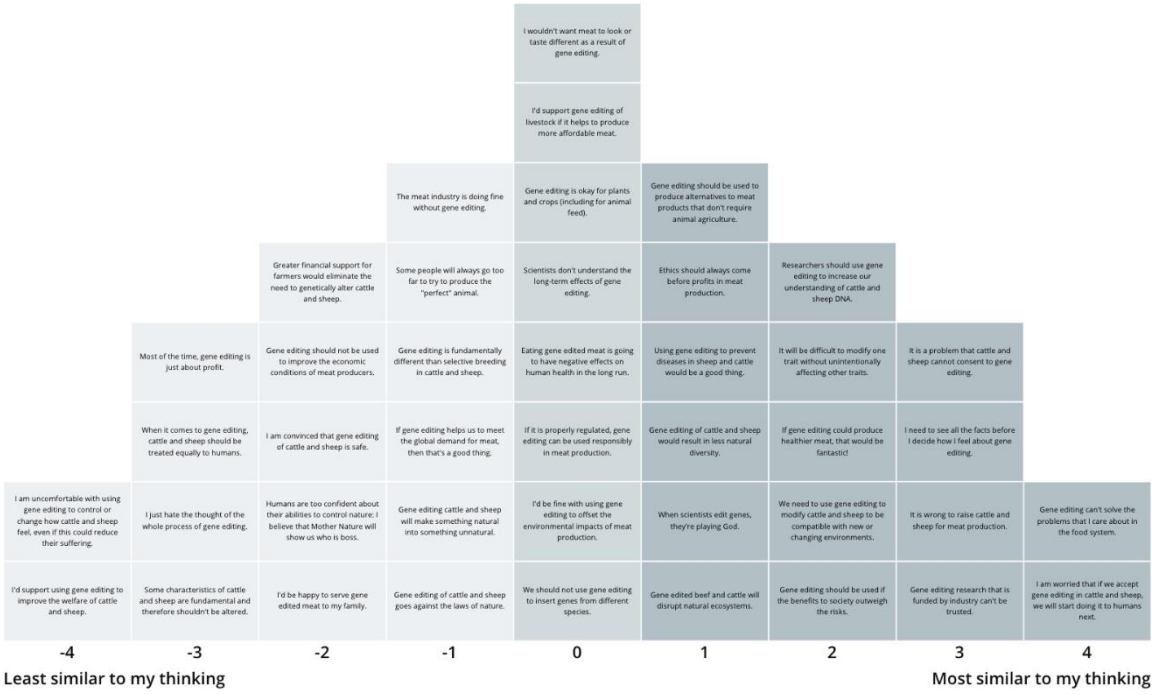
(#16, -2) as well as concerns about disruptions to natural ecosystems that might adversely affect food production (#10, +1; #22, +1). Conversely, Discourse 4- is similar to Discourse 3 in its concern for the potential impact of gene editing on livestock used in meat production (inverse of #35, -3; #21, -3; #18, -4).

Both the bipolarity of Discourse 4 and the ambivalence of associated participants toward gene editing makes it a difficult discourse to interpret. It encompasses apparent contradictions, such as the combination in Discourse 4+ of problematising the fact that animals cannot consent to gene editing (#5, +3) and no apparent feeling discomfort with using gene editing to control how cattle and sheep feel (#18, -4). It is possible that the contradictory responses and ambivalence of its associated participants reflects the fact that Discourse 4 is a temporary or what is termed a 'working' discourse for people who are genuinely undecided about the topic.

The representative Q-sort for Discourse 4+ is shown in Figure 14 (the representative Q-sort for Discourse 4- is the mirror image of this Q-sort).

Figure 14: Representative Q-sort for Discourse 4

Statements that are ranked furthest to the left in the grid are those that are least similar to the views of Discourse 4, while statements that are furthest to the right are those that are most similar to the views of Discourse 4. Statements that are near the centre of the grid are those that people associated with Discourse 4 tend to feel neutral or unsure about. Statement ranks for each discourse are also shown in Table 3.



4.2.5. Discourse 5: Open for abuse

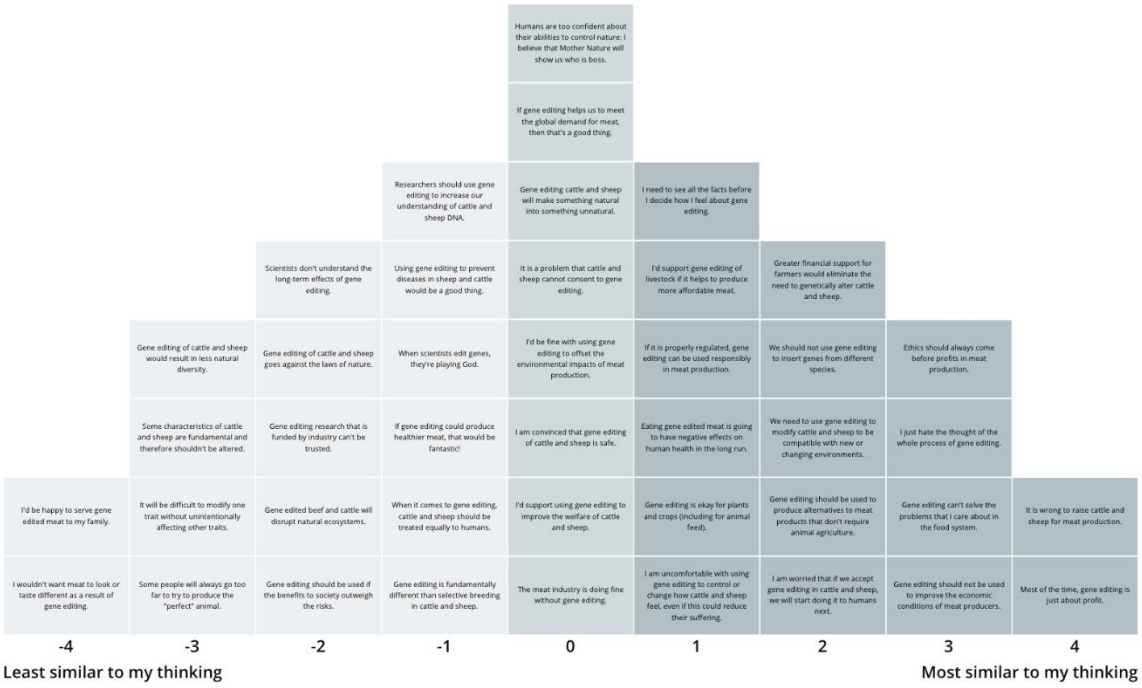
Discourse 5 is distinctive because it is primarily concerned with the possibility that gene editing will be misused for the sake of profit. People associated with Discourse 5 believe that profit is the primary motivation for gene editing (#39, +4) and seek to remove profit as a motivating factor for its use in beef and sheepmeat production (#16, +3; #26, +3; #28, +1; 36, +2).

Focus group participants who were associated with this discourse tended to emphasise the need for appropriate legislation, regulation, and oversight of gene editing. Nevertheless, those associated with Discourse 5 do not take a strong stance on whether appropriate regulation will ensure that gene editing is used responsibly (#33, +1).

Despite a seeming mistrust of actors involved in gene editing, Discourse 5 evidences a relatively high level of trust in scientists and their ability to produce credible research (#40, -2), to understand and manage the long-term effects of gene editing (#2, -2; #6, 0; #7, -3), and to not go too far in trying to produce "perfect" production animals (#32, -3).

Figure 15: Representative Q-sort for Discourse 5

Statements that are ranked furthest to the left in the grid are those that are least similar to the views of Discourse 5, while statements that are furthest to the right are those that are most similar to the views of Discourse 5. Statements that are near the centre of the grid are those that people associated with Discourse 5 tend to feel neutral or unsure about. Statement ranks for each discourse are also shown in Table 3.

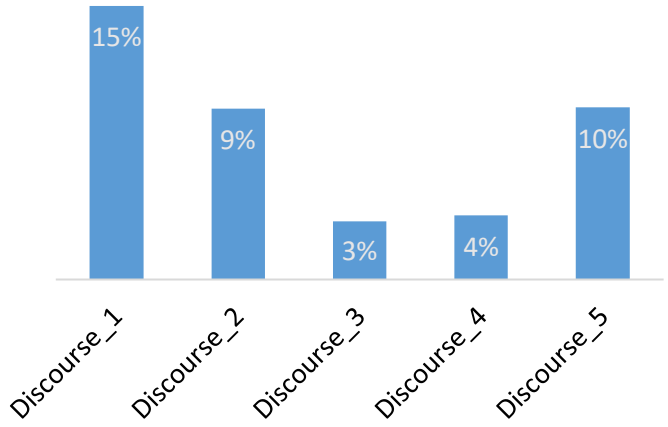


4.3. Prevalence of the identified discourses on gene editing in livestock production

The prevalence and distribution of the identified discourses was assessed as part of the community survey. Almost 50% of survey respondents were not associated with any of the five discourses, or with any combination of two discourses (47%, n=2146). However, 41% of respondents were associated to a single discourse, and the remaining 12% of respondents were associated with two discourses. The distribution of z-score for the five discourses can be found in Figure 48 in Appendix G.

Discourse 1 was the most prominent discourse, with 15% of survey respondents solely and positively associated with this discourse (see Figure 16). Discourses 5 and 2 were the next most prominent discourses, associated with 10% and 9% of survey respondents respectively. Discourses 2 and 5 were also strongly correlated (Pearson's correlation coefficient of 0.6280) and 7% of survey respondents were associated with both discourses, which suggests that Discourses 2 and 5 are capturing two expressions of the same discourse, rather than being two distinctive discourses. No other combination of discourses was associated with more than 1% of survey respondents. Discourses 3 and 4 were only associated with a small number of survey respondents (3% and 4% respectively).

Figure 16: Percentage of community survey respondents who are positively associated with each of the five identified discourses (n=2146)



4.3.1. Distribution of the identified discourses on gene editing in livestock production

To better understand whether the different discourses were associated with different groups within the Australian community, we collected information on survey respondents' age, gender, and diets. Consistent differences in association with the five discourses were identified across age groups, between male and female respondents, and between respondents with different diets:

- *Age:* Younger survey respondents were more likely than expected to be associated with Discourses 3 and 4. Conversely, older respondents were less likely than expected to be associated with these discourses (see Figure 17).
- *Gender:* Male respondents are overrepresented in Discourse 1 by more than 10% comparatively, while women are underrepresented in Discourse 1 by the same amount. Male respondents are also somewhat overrepresented in Discourse 4 (see Figure 18).

- *Diet:* Omnivores are underrepresented by over 20% in Discourse 3 and are somewhat overrepresented in Discourses 1 and 5. Conversely, flexitarians, vegetarians, and vegans are overrepresented in Discourse 3 and to a lesser extent in Discourse 4 (see Figure 19). This supports our findings in the original Q-sort where all but one of the six positively-associated participants consumed alternative diets (including vegetarian, vegan, pescatarian, and flexitarian diets).

Figure 17: Association between respondents' age and preferred discourse (n=2146)

The upper figures show the actual (grey) and expected (red) percentage of each age group for each discourse, including those participants who are associated with multiple discourses ('multi'), and no discourse ('unassigned'). The lower figures show the percentage difference between the actual and expected number of respondents from each age group for each discourse.

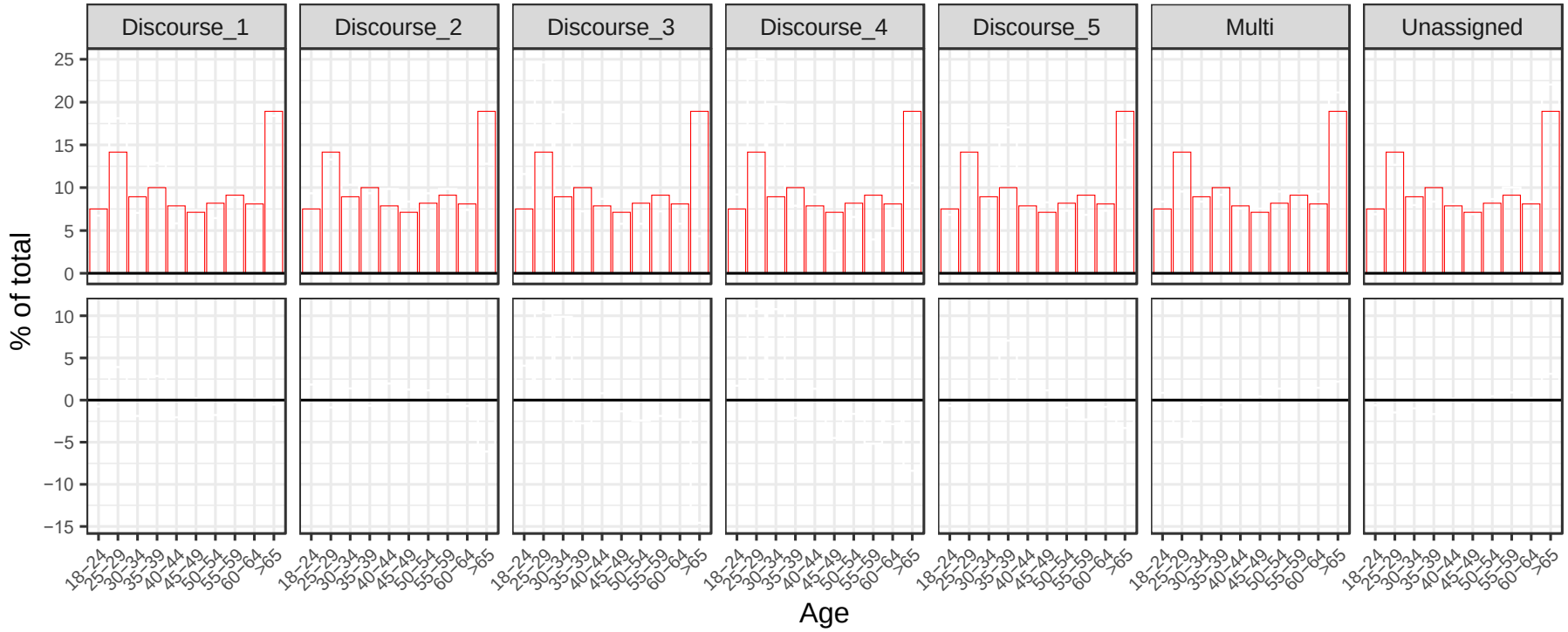


Figure 18: Association between respondents' gender and preferred discourse (n=2146)

The upper figures show the actual (grey) and expected (red) percentage of male and female respondent associated with each discourse, including those participants who are associated with multiple discourses ('multi') and no discourse ('unassigned'). The lower figures show the percentage difference between the actual and expected number of male and female respondents for each discourse.

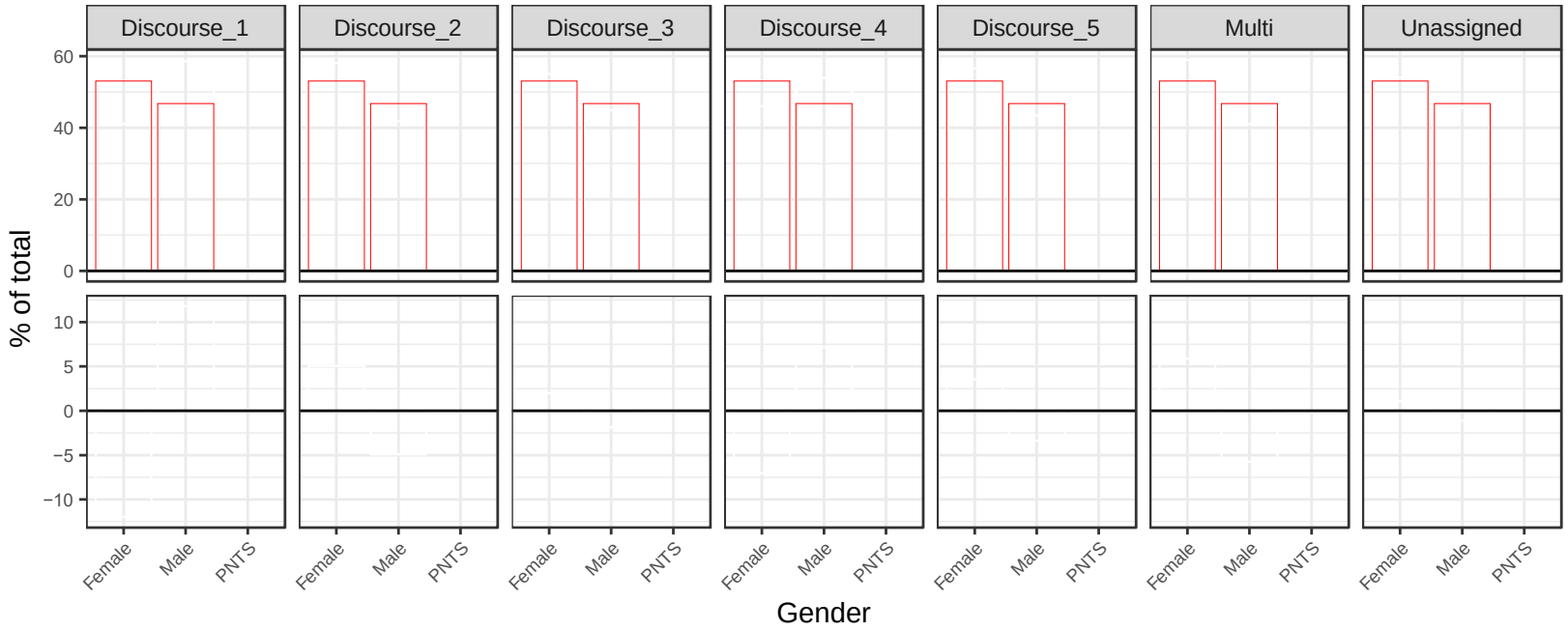
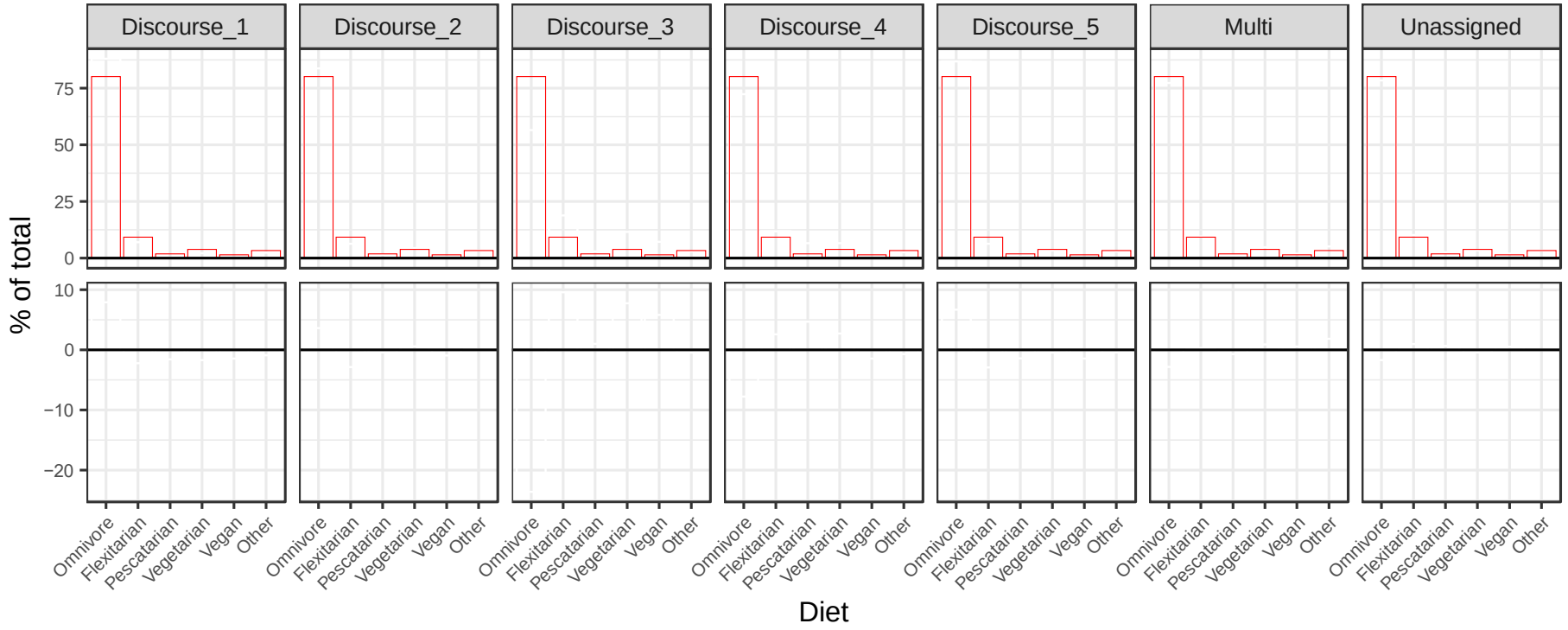


Figure 19: Association between respondents' diet and preferred discourse (n=2146)

The upper figures show the actual (grey) and expected (red) percentage of respondents with dietary preferences associated with each discourse, including those participants who are associated with multiple discourses ('multi'), and no discourse ('unassigned'). The lower figures show the percentage difference between the actual and expected number of respondents with dietary preferences for each discourse.

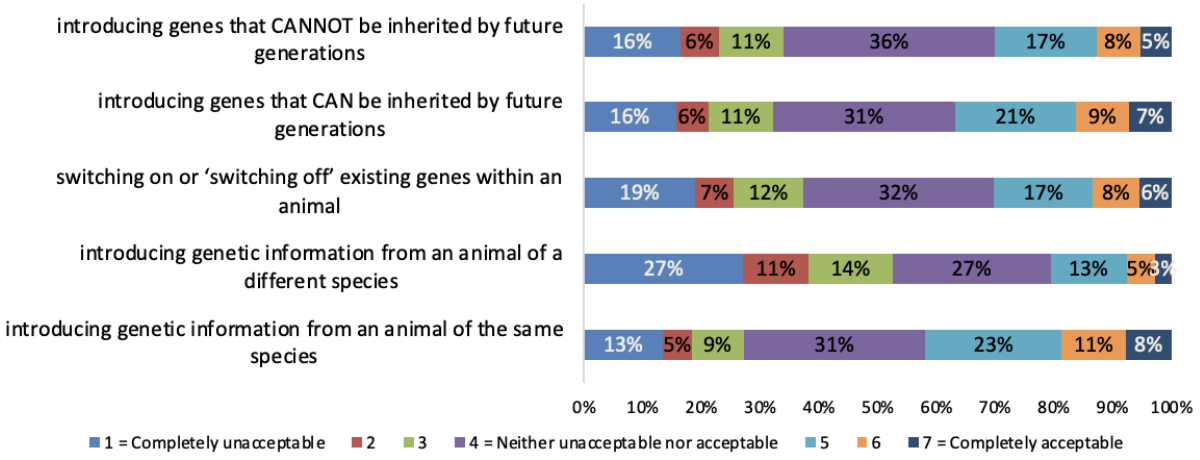


4.4. Acceptability of types of gene editing interventions

Apart from introducing genetic information from another species, there were no strong differences between the acceptability of different types of gene editing (see Figure 20). Between 27% and 36% of survey respondents did not consider any of the surveyed uses of gene editing to be either acceptable or unacceptable. Similar numbers of survey respondents were accepting of gene editing that made heritable and non-heritable changes to livestock (37% and 30% respectively). This result corresponds with qualitative findings from the focus groups, in which concerns about the heritability of altered genes were infrequently raised by participants. There were, however, clear differences in respondents' acceptance of introducing genetic information from the same or different species: 27% of survey respondents considered introducing genes from another species to be completely unacceptable, and this was the only type of gene editing to be viewed as somewhat or completely unacceptable by over 50% of respondents. In contrast, only 27% of survey respondents considered introducing genes from the same species to be unacceptable.

Figure 20: Levels of acceptance for each of the surveyed types of gene editing

Provided in terms of percentage of survey respondents (n=2146) who answered the question, "Using a scale of 1–7, where 1 is completely unacceptable and 7 is completely acceptable, please indicate how acceptable you feel it would be to alter the genes of cattle or sheep by…"



4.5. Acceptability of specific applications of gene editing in beef and sheepmeat production

The discourses described in Section 4.2 suggested that while community attitudes toward gene editing vary, they often depend on the specific ways in which the technology will be applied within beef and sheepmeat production. This section draws on results from the community survey and focus groups to assess the ethical acceptance of prospective applications of gene editing in beef and sheepmeat production, as well as the reasons given by participants for key differences.

Among the surveyed applications of gene editing, there was a clear preference among respondents for those applications that are aimed at directly benefiting animal health and welfare (see Figure 21). Over 50% of survey respondents rated the use of gene editing to increase disease resistance, reduce the need for painful or stressful procedures, and reduce the ability of pests to reproduce as being either somewhat or completely ethically acceptable. Applications that aim at addressing environmental concerns or helping to produce healthier meat products were also viewed as acceptable by approximately 50% of survey respondents. Conversely, survey respondents found applications that aim to improve production output or efficiency, such as enhancing feed efficiency (by enhancing abilities to digest lower quality feed), muscle mass, and the ratio of male births to be relatively unacceptable. Given the prioritisation of animal welfare by many respondents, this result is perhaps unsurprising, particularly because these types of applications were seen by many in the focus groups as actually or potentially having negative effects on animal welfare and primarily aimed at increasing profits. The only application of gene editing that was considered somewhat or completely unacceptable by close to 50% of survey respondents was to enhance the ability of cattle and sheep to digest lower-quality feed. Roughly equal proportions of respondents considered gene editing to be unacceptable, neither unacceptable nor acceptable, or acceptable if it were used to alter livestock temperament or coat properties, or to enhance meat quality.

Finally, each application of gene editing was rated as being neither unacceptable nor acceptable by between 21% to 32% of respondents. This result is similar to responses about types of gene editing (Figure 20) and might suggest that a considerable portion of the Australian community has not yet formed strong opinions about the ethical acceptability of gene editing in beef and sheepmeat production or does not feel sufficient informed or engaged to have clear views. However, 8% of participants rated all of the surveyed applications as being either somewhat or completely unacceptable. Of these, 97% stated that gene editing is always unacceptable in livestock production, no matter how it is used. Conversely, 9% of survey participants rated all of the applications mentioned in the survey as being either somewhat or completely acceptable, of which 66% felt that gene editing is always acceptable in livestock production.

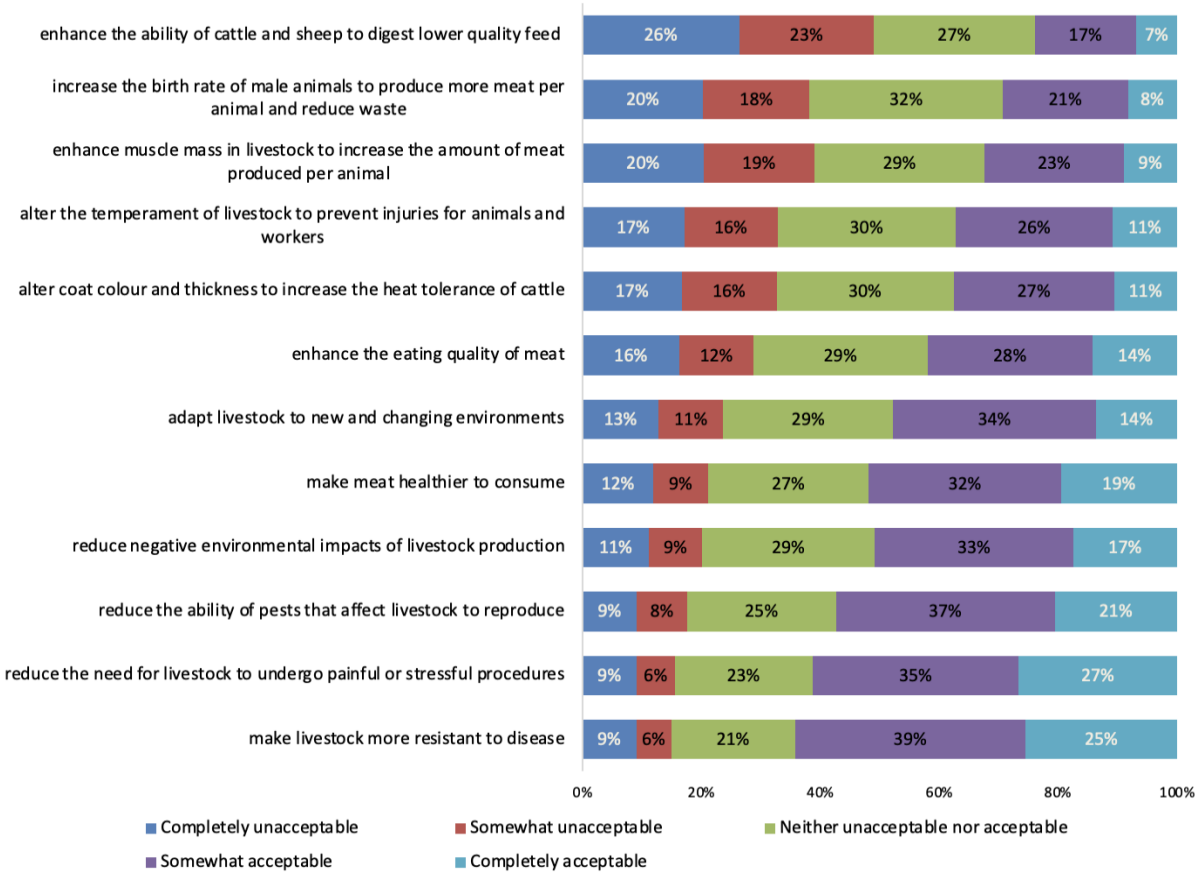
The survey findings regarding the ethical acceptability of different gene editing applications in livestock production echo sentiments expressed by participants in the community focus groups, as well as the identified discourses. For example, participants aligned to Discourses 1 and 3 are tentatively supportive of gene editing to improve animal health and welfare but are sceptical of uses that are perceived as solely benefiting the meat industry. Discourse 4 reflects an undecided view on gene editing in which associated participants are actively weighing the risks and benefits but have not yet formed strong opinions. Finally, Discourses 2 and 5 are generally opposed to all applications of gene editing in livestock production. Similarly, participants in the preliminary focus groups showed relatively high levels of acceptance for applications that directly improved livestock health or the nutritional quality of meat. Conversely, many focus group participants were particularly averse to uses

of gene editing that altered the animals' appearance or temperament, or which altered the ratio of male to female animals.

Qualitative results from the preliminary and confirmatory focus group discussions highlight several considerations that underlie the acceptability or unacceptability of different gene editing applications. These include animal welfare concerns, the perceived need for intervention, the balance of benefits and risks, the availability of alternatives to gene editing, and the importance of the issue addressed by the proposed intervention, as well as feelings of discomfort with the specific proposed change. Each of these factors is discussed below.

Figure 21: Levels of acceptance for each of the surveyed application of gene editing

Provided by percentage of survey respondents (n=2146) who answered the question, "How ethically acceptable or unacceptable do you feel it is to use gene editing to…"



4.5.1. Animal health and welfare

Overall, focus group participants emphasised considerations about the health and welfare of cattle and sheep when determining the acceptability of various uses of gene editing. For example, the use of gene editing to make livestock more resistant to disease was clearly preferred by most, and was seen as similar to applications of technologies to improve human health. Gene editing to introduce the polled gene to cattle was viewed by most focus group participants as an acceptable application of the technology, as it could replace an existing procedure that causes pain and stress to the animals involved. Further, many participants generally felt that this use of gene editing would also benefit the producer and had few obvious downsides. However, a smaller but vocal group of participants remained concerned about changing what they consider to be the "natural qualities" of the animal such as horns and the safety of hornless animals, and argued that the removal of horns is unnecessary since improved husbandry practices or reduced meat consumption could make such interventions unnecessary. They tended to dispute whether there was a problem that needed to be solved in this space.

4.5.2. Perceived need for intervention

Focus respondents often distinguished between applications of gene editing that were perceived as necessary for addressing what they viewed as important or pressing problems (such as reducing risk of diseases in livestock including those affecting reproduction) and applications where alternative approaches might be available, which they often viewed as preferable. For example, in the following quote, a female focus group participant argues that the use of gene editing to increase muscle growth in cattle and sheep is not acceptable because it is not required to ensure the survival of either humans or livestock species:

> *We have other food options and they're not endangered so I think changing those sorts of things are financial [sic] related and not necessary.*

The use of gene editing to alter the nutritional quality, or healthiness, of meat was controversial for this reason. Some people viewed this as an opportunity to improve diet-related public health, and especially the health of those people who consume a lot of meat. However, other focus group participants felt that increased meat consumption should not be encouraged due to possible negative environmental or animal welfare implications, and that people could improve dietary health by reducing their meat consumption.

This theme tended to split depending on whether people viewed the issue at stake as a 'real' concern versus those who rejected the framing of the problem and hence the proposal of gene editing as a solution. The latter tended to generally be more sceptical about industrial scale farming and practices within it.

4.5.3. Perceived benefits

The acceptability of different applications of gene editing in livestock production frequently depended on whether focus group participants perceived the benefits of gene editing as outweighing the risks. For example, enhancing disease resistance in beef cattle and meatsheep and reducing the need for painful or stressful procedures were often viewed as having simultaneous benefits for livestock welfare and potentially the health of producers, without obvious and specific downsides for any stakeholders, and were therefore considered more acceptable by many focus group participants. This

point of view is illustrated by a quote from a male focus group participant from Victoria, in relation to using gene editing to breed polled cattle:

> *What a fantastic idea. It's great for the calves, in such, they don't have to suffer any unnecessary pain. Also if the meat quality is better than crossbreeding, then why not?*

Conversely, applications of gene editing that were not perceived as having clear benefits to the animals themselves, such as altering the appearance of livestock or changing their temperament to make them easier to handle, tended to be viewed as unacceptable when weighed against the inherent and unknowable risks that participants tended to associate with altering animals' genes. In such cases, participants often questioned why anyone would want or need to make such a change and did not feel that improved safety of farm workers justified such a change. Again, they tended to reject the framing of the issue at hand as a problem, but suggested that a more clearly elaborated and defended purpose for the change, particularly in terms of the animal's own benefit, might influence their views. More generally they tended not to see increased profits or efficiency of production as a benefit, and in fact often viewed gene edits that would produce these outcomes as open to abuse and hence that they presented significant risks.

4.5.4. Naturalness

For other applications, such as altering the temperament of cattle and sheep or the ratio of male to female births, the lack of acceptance by many participants appeared to be determined less by the perceived benefits and risks of the application or a reaction to gene editing itself, than by visceral feelings that the proposed changes constituted "going too far" with this technology and even that it represented an abuse of it. They tended to focus on the idea that these types of gene editing would alter what they viewed as "natural" characteristics of animals in a way that was unethical. These opinions tended to hold even among those who were well-aware that production animals have been altered over millennia through selective breeding to enhance or reduce certain traits. Several people independently raised the prospect that altering animals' temperament or ability to feel pain would create what they called "zombie cows" with significantly reduced welfare and unnatural characteristics. This view is illustrated by the following quote from a male participant from South Australia:

> *that would turn animals into zombies, no feelings, no characteristics, basically a meat factory on legs...*

This viewpoint reflects two more general considerations seen in our study respondents: their sense of the "natural" was often very strong even if it was arguably not well grounded in the history of agriculture and tended to be very general and not well defined; nevertheless, reference to the "natural" frequently arose as a sort of trump card or bottom line for some participants. Second, gene editing for many participants made them think about science fiction scenarios common in popular culture, and hence much of what was seen as "going too far" was cast in these terms.

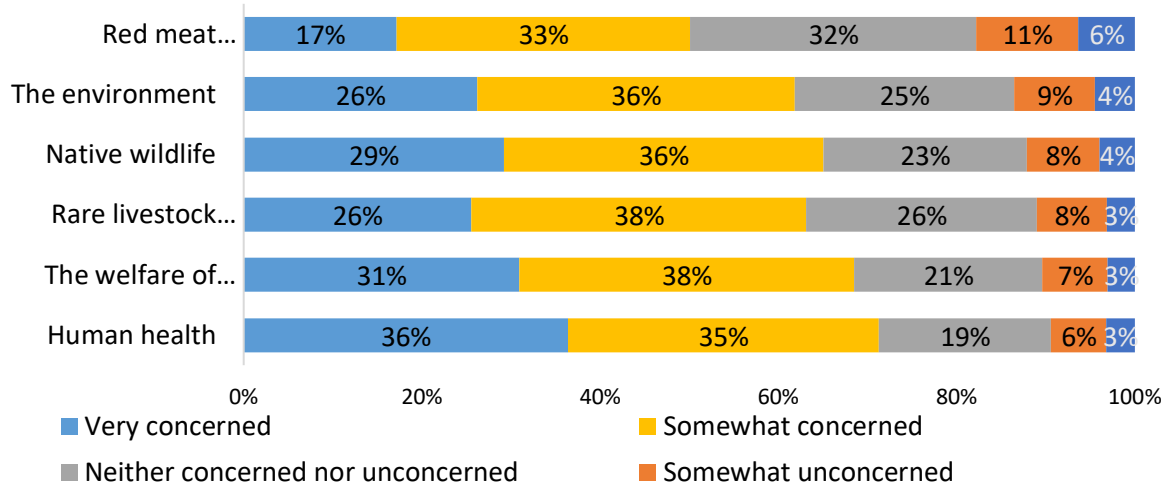
4.6. Perceived risks of gene editing in beef and sheepmeat production

More generally, both focus group participants and survey respondents expressed concerns about the potential that the long-term consequences of gene editing are currently unknown or may be unknowable. When asked about their level of concern about the potential risks from the use of gene editing in beef and sheepmeat production, respondents in the community survey echoed the concerns raised by participants in the confirmatory focus groups (see Figure 22). Between 50% to 71% of respondents were either somewhat concerned or very concerned about each of the surveyed risks. Risks to human health and livestock welfare were the highest rated risks.

Human intervention in nature was often cited as a source of the risks associated with gene editing. Several participants stated that there are always risks when humans intervene in nature and that "nature will show us who's boss." However, focus group participants were also concerned about the potential for misuse of the technology by bad actors.

Figure 22: Percentage of survey respondents and their concern for perceived risks of gene editing in Australian livestock production (n=2146)

Responses given on Likert-type scale from completely unconcerned to very concerned



4.7. Factors affecting public attitudes toward the use of gene editing in beef and sheepmeat production in Australia

To examine the drivers that influence different attitudes toward gene editing and its prospective applications in beef and sheepmeat production within the Australian community, we assessed the relationships between community attitudes and several variables (see Section 3.3) based on responses to the community survey. The examined variables include participants' level of familiarity with gene editing, as well as their overarching attitudes toward livestock production and technological development.

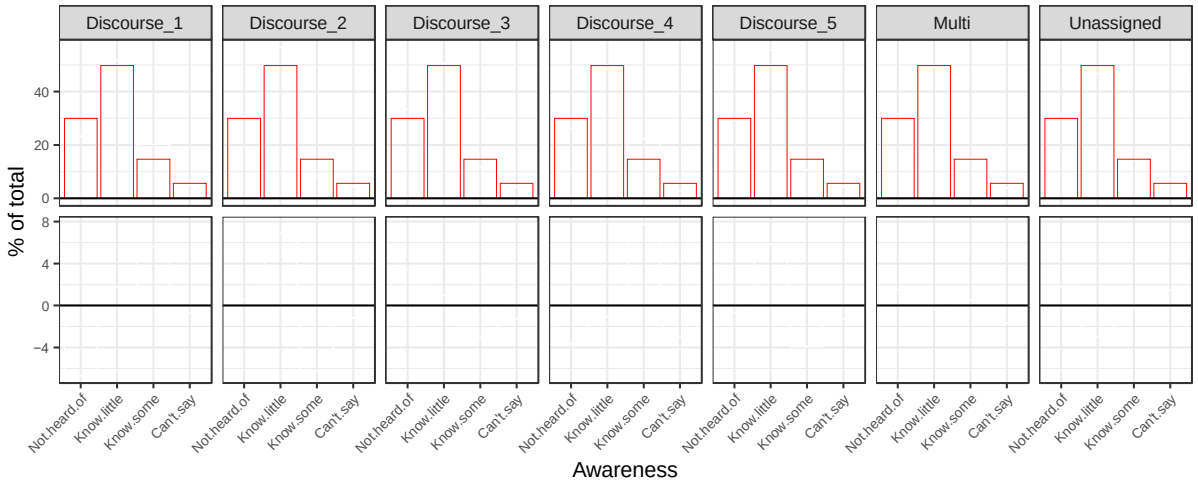
4.7.1. Awareness of gene editing

Overall, survey respondents' self-rated awareness of gene editing was relatively low, substantiating our experiences in the preliminary and confirmatory focus groups. Half of the surveyed respondents reported that they had heard of but knew little or nothing about gene editing (50%, n=2146), while

30% had never heard of gene editing, and 15% felt that they knew enough about it that they could explain gene editing to a friend. However, only modest differences (<10%) were found in respondents' self-reported awareness of gene editing across the five discourses (see Figure 23), suggesting that perceived awareness of gene editing is not influencing respondents' association with the identified discourses.

Figure 23: Association between survey respondents' self-reported awareness of gene editing and preferred discourse (n=2146)

The upper figures show the actual (grey) and expected (red) percentage of respondents with different levels of self-reported awareness associated with each discourse, including those participants who are associated with multiple discourses ('multi') and no discourse ('unassigned'). The lower figures show the percentage difference between the actual and expected number of respondents with different self-reported awareness of gene editing for each discourse.



4.7.2. Overarching views on Australian livestock production

In contrast to awareness of gene editing, respondents' overarching views on Australian livestock production were clearly associated with some discourses. Discourses 3 and 4 were particularly prominent among survey respondents who disagreed with the statement, "People have a right to eat meat" (see Figure 24). Conversely, survey respondents who strongly agreed with the statement were somewhat overrepresented in Discourse 1. Similarly, respondents who are associated with Discourse 3 and Discourse 4 tend to agree with the statement, "It is wrong to raise cattle and sheep for meat production," while respondents associated with Discourse 1 tend to disagree with this statement (see Figure 25). General attitudes toward the use of animals in meat production is therefore a likely driver of the attitudes expressed toward the use of gene editing in Discourses 3 and 4.

Overarching views on livestock production were also associated with different views on the applications of gene editing in beef and sheepmeat production. A positive attitude toward livestock production tends to correlate with more positive attitudes toward all the surveyed applications of gene editing. However, this view is particularly correlated with applications that aim to enhance the quality characteristics meat, as well as applications to improve production output and efficiencies (see Table 9, Appendix H).

Figure 24: Association between survey respondents' agreement with the statement "People have a right to eat meat" and preferred discourse (n=2146)

The statement was rated on a Likert-type scale from 1 = completely disagree to 7 = completely agree. The upper figures show the actual (grey) and expected (red) percentage of respondents for each rating each discourse, including those participants who are associated with multiple discourses ('multi') and no discourse ('unassigned'). The lower figures show the percentage difference between the actual and expected number ratings for each discourse.

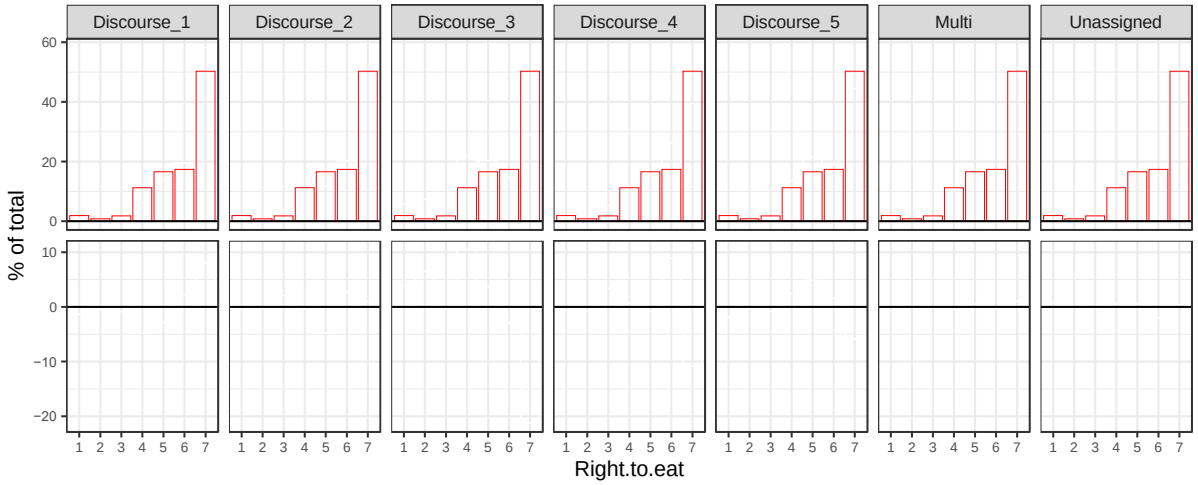
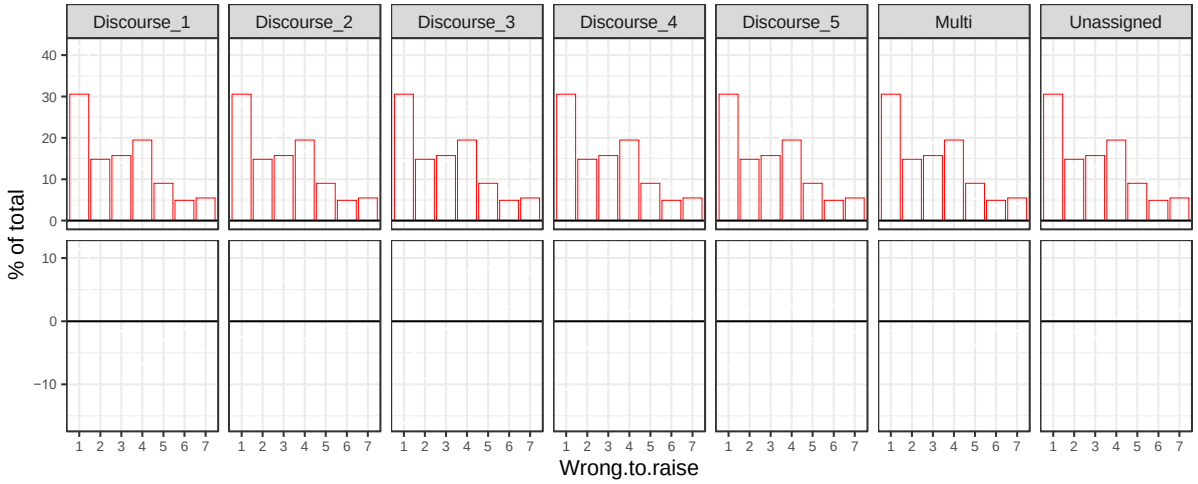


Figure 25: Association between survey respondents' agreement with the statement "It is wrong to raise cattle and sheep for meat production" and preferred discourse (n=2146)

The statement was rated on a Likert-type scale from 1 = completely disagree to 7 = completely agree. The upper figures show the actual (grey) and expected (red) percentage of respondents for each rating each discourse, including those participants who are associated with multiple discourses ('multi') and no discourse ('unassigned'). The lower figures show the percentage difference between the actual and expected number ratings for each discourse.

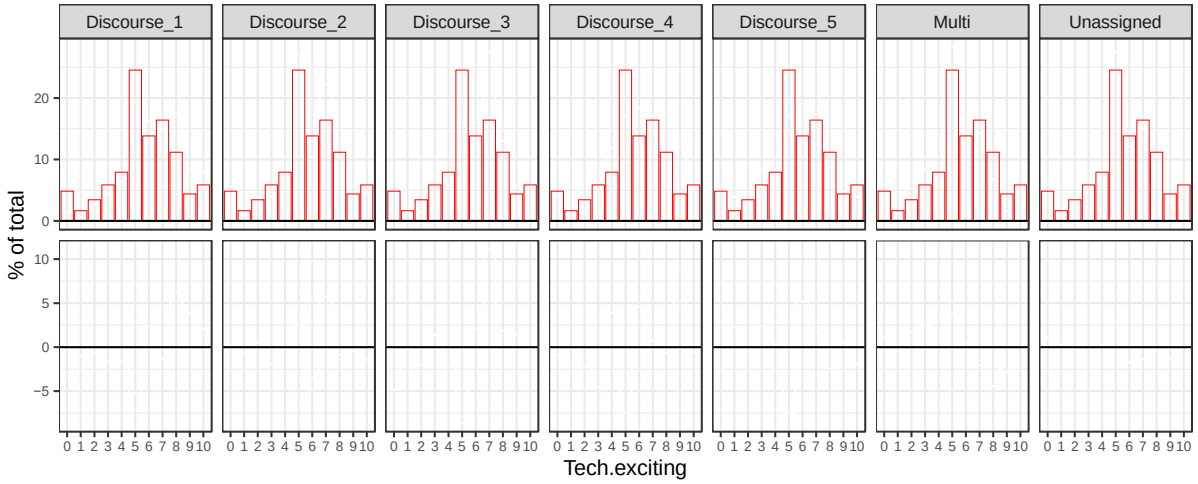


4.7.3. Overarching views on science and technology

Survey respondents who expressed different views on science and technology also tended to be associated with different discourses on gene editing. In particular, positive association with Discourses 1, 3, or 4 was also associated with greater excitement than concern regarding novel technologies (see Figure 26), suggesting that attitudes toward technology was not a differentiating factor between these discourses.

Figure 26: Association between survey respondents' agreement with the statement "New technologies excite me more than they concern me" and preferred discourse (n=2146)

The statement was rated on a Likert-type scale from 1 = completely disagree to 7 = completely agree. The upper figures show the actual (grey) and expected (red) percentage of respondents for each rating each discourse, including those participants who are associated with multiple discourses ('multi') and no discourse ('unassigned'). The lower figures show the percentage difference between the actual and expected number ratings for each discourse.



4.8. Trust in actors involved with gene editing in beef and sheepmeat production

As noted previously, the community does not trust all actors associated with the deployment of gene editing in the livestock sector. One of the key factors influencing trust, as revealed by the qualitative content analysis of the focus groups, was the perception of vested interests, as seen particularly in responses to the question "How much do you trust these institutions and the people involved in them to develop and regulate gene editing in a way that you agree with?" Trust was lowest when participants felt that parties had the most to gain financially from gene editing, as noted by one participant:

Anything that involves profit has the potential for greed over ethical behaviour.

Although it was noted by several focus group participants that scientists and academics are reliant on funding, often from industry, they were considered the most trustworthy because of their knowledge and experience, and the idea that scientists and academics are working for the benefit of society and for animals. CSIRO was identified by participants as a trustworthy organisation. Nevertheless, results from the community survey show that the community has fairly mixed trust in the abilities of scientists

to accurately predict the consequences of changes made through gene editing (see Figure 27) and were also sceptical of their motivations (Figure 28).

Figure 27: Survey respondents' level of agreement with the statement, "Scientists can accurately predict the outcomes of changes made through gene editing in livestock" (percentage of n=2146)

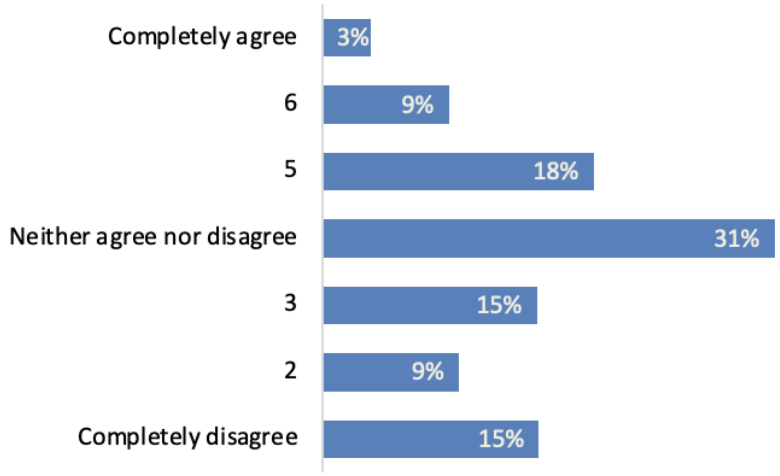
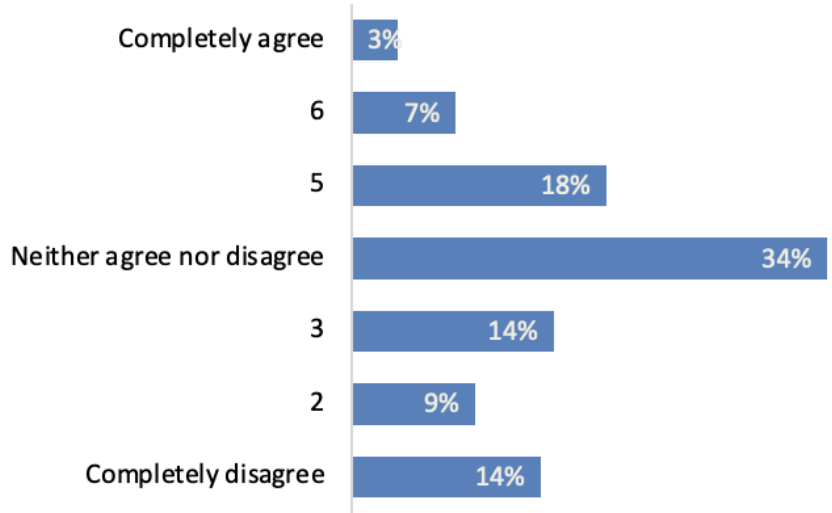
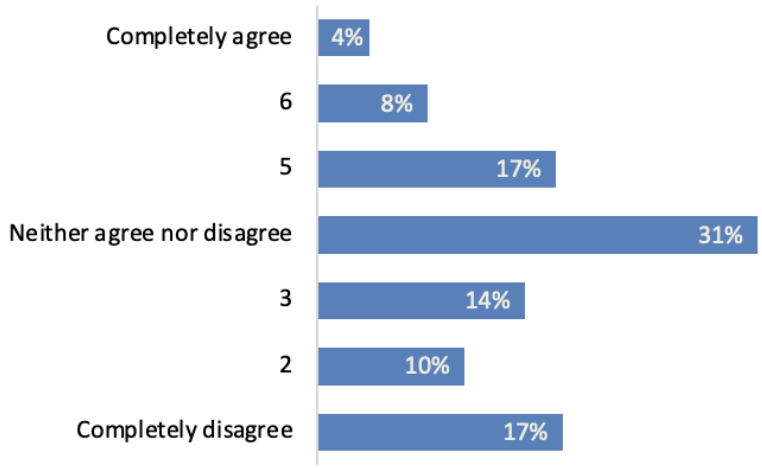


Figure 28: Survey respondents' level of agreement with the statement, "Scientists and breeding companies have motivations that I agree with" (percentage of n=2146)



Focus group participants also indicated that they trusted a regulatory organisation, although they did not specify a current regulatory organisation. They suggested that an independent regulatory organisation would act as a watchdog to ensure that standards were met and would have the experience to do so. In contrast, both in the focus groups and community survey, community members had little trust in self-regulation of gene editing by the meat industry (see Figure 29)

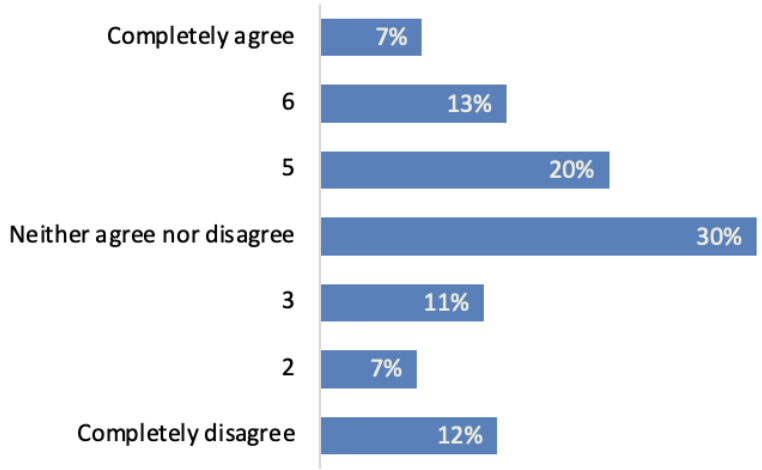
Figure 29: Survey respondents' level of agreement with the statement, "The meat industry will appropriately self-regulate the use of gene editing for livestock production" (percentage of n=2146)



Interestingly, although it may be expected that not-for-profit and charity organisations would be seen as highly trustworthy given their supposed lack of vested interests, some participants commented that these organisations have "their own agendas" and hence were less trusted than scientists, academics, and regulators.

Trust in governments was mixed among focus group participants. Governments were trusted to implement policy and create legislation related to regulation, but they were also seen by some to be potentially manipulated by "big business" and individual politicians were seen as fallible. Results from the community survey bear out the finding that trust in government is mixed as are the levels of trust in the federal government's ability to appropriately regulate the use of gene editing in livestock production (see Figure 30).

Figure 30: Survey respondents' level of agreement with the statement, "The federal government of Australia will appropriately regulate the use of gene editing for livestock production" (percentage of n=2146)



Organisations that were trusted the least included industry organisations, businesses involved in gene editing and commercial producers, although some participants did suggest that industry organisations and farmers have experience and knowledge especially related to animal welfare.

Overall, participants wanted a variety of organisations and stakeholders involved in decision-making about the use of gene editing in livestock production, with decision-making weighted to those with

relevant knowledge (in particular about animal welfare) and independence. This approach was seen to overcome the almost inevitable risk of individuals acting unethically out of self-interest. Participants wanted oversight, transparency, guidelines, principles, audits, and accountability. Ultimately participants acknowledged the challenges of balancing industry profitability and ethical and trustworthy behaviour. As noted by one participant:

> *I think they all have knowledge in individual areas and have their own cause and agendas. As for trust, I guess I don't have much trust in those who are doing it for profit only. At the same time, profit needs to be made but how to make profit with being honest and ethical is something I don't know how to answer myself.*

4.9. Communicating about gene editing

In order to develop a community engagement strategy, it is important to explore message-related factors such as who should communicate about issues, as well as how those issues should be framed for different audiences. Factors such as trust, and perceptions of bias, credibility, and the motivations of actors, influence decisions about who should be involved in communication.

4.9.1. Messenger effects on attitudes toward the use of gene editing in beef and sheepmeat production

As noted previously, to explore whether different actors were trusted to communicate about gene editing, participants watched an actor playing either a 'scientist' or a 'farmer' deliver a short message about the benefits of the technology in livestock production at the end of the informative video about the science of gene editing.

The results of the video treatments showed small, but consistent, effects of the video treatments on the post-video responses, after accounting for pre-existing attitudes toward the livestock industry and technology. Figure 31 (right) illustrates that the participants who watched the video with the added message from a scientist were more likely to support the use of gene editing in meat production (giving scores of 6 to 10) than those participants who watched the video with the farmer. Participants who watched the farmer video were also more likely to think that gene editing would make things either better or worse in the future, while those who watched the scientist video tended to be more uncertain about the future impact of gene editing (see Figure 31, left).

The most notable differences in responses between the two treatments relates to the perceived goals of gene editing for the meat industry, researchers, and to a lesser extent individual producers (Figure 32). Participants who watched the scientist version of the video were over 15% more likely than those who watched the farmer video to consider increased production output to be the primary goal of gene editing for the meat industry, and over 10% more likely to also think this is the main goal for researchers. Meanwhile, participants who watched the farmer video were more likely to consider increased sustainability to be the primary goal for both industry and researchers.

Figure 31: Effects of the two video treatments ('scientist' and 'farmer') on focus group participants' attitudes toward gene editing and its use in meat production

The y-axis shows the percentage difference between the two treatments for each response to the questions, "Do you think gene editing will generally improve our way of life in the future, OR have no effect, OR make things worse in the future?" (left); and "On a scale of 0–10, where 10 is completely supportive and 0 is completely against it, please indicate how supportive you are of the use of gene editing in Australian beef and sheepmeat production?" (right). Positive scores for a response show that participants who watched the 'scientist' video were more likely to give that response, while negative scores show that the participants who watched the 'farmer' video were more likely to give the associated response.

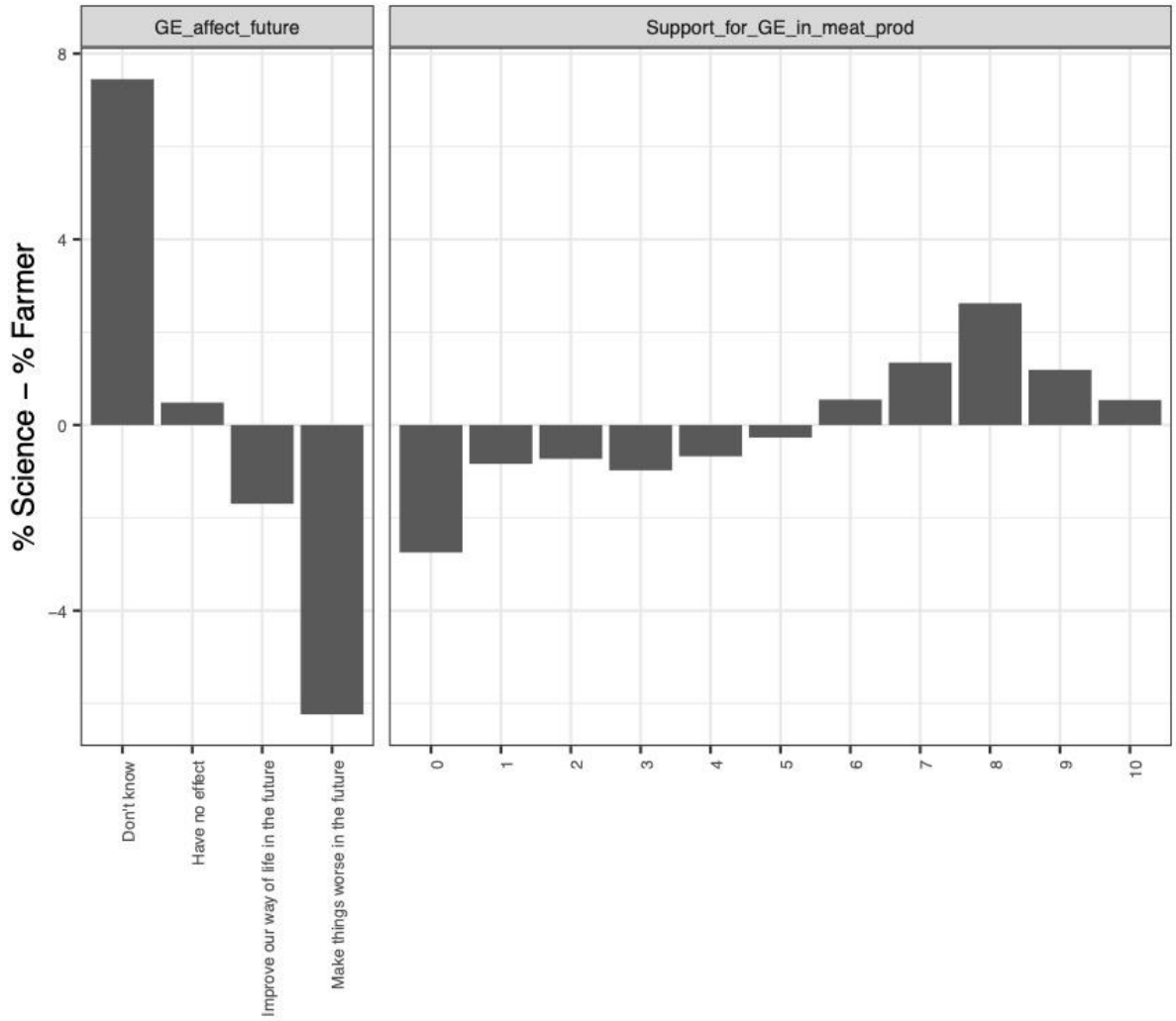
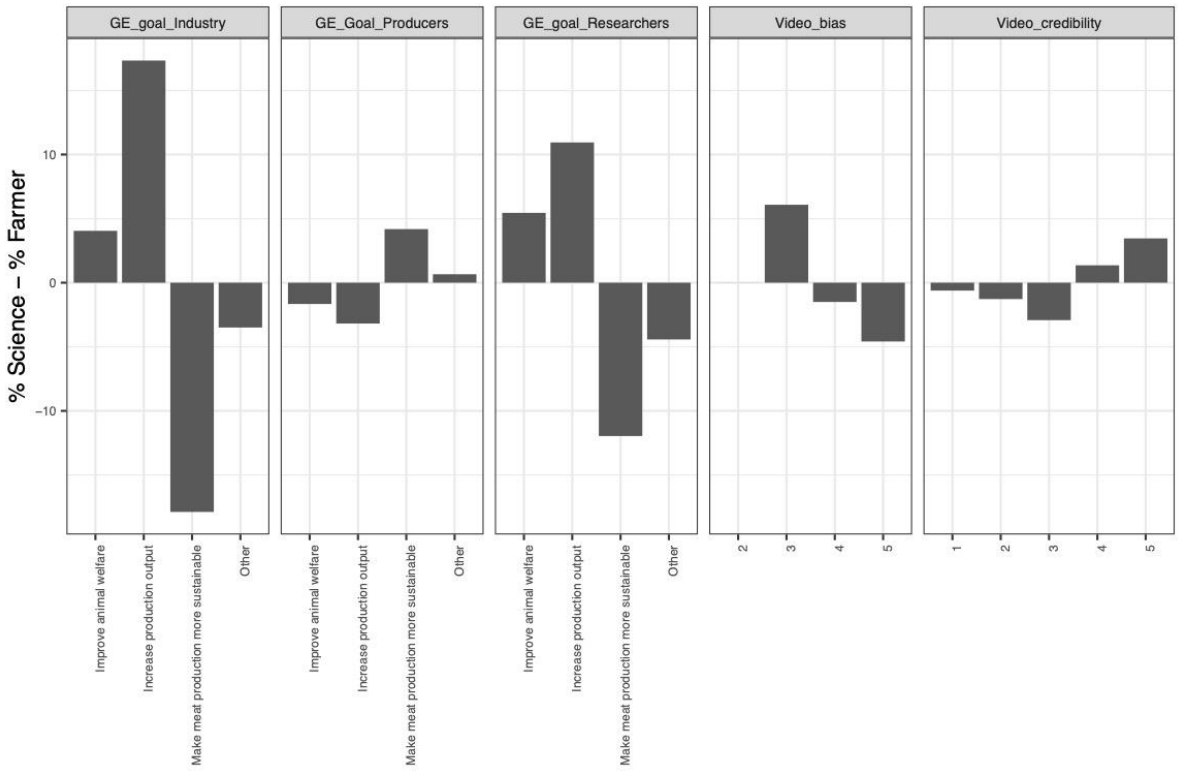


Figure 32: Effects of the two video treatments ('scientist' and 'farmer') on focus group participants' attitudes toward gene editing and its use in meat production

The y-axis shows the percentage difference between the two treatments for each response to the questions (from left to right), "In your view, what do you think is the primary goal of gene editing for the Australian beef/sheepmeat industry as a whole? / Individual beef/sheep producers? / Researchers?"; "In your view, was the introductory video: 1=completely biased against gene editing to 5=completely biased in favour of gene editing"; and "How credible did you find the information in the video?" (1=completely uncredible to 5=completely credible). Positive scores for a response show that participants who watched the 'scientist' video were more likely to give that response, while negative scores show that the participants who watched the 'farmer' video were more likely to give the associated response.



4.9.2. Messenger effects on the perception of information about gene editing

Finally, the video treatment also had small, but consistent, effects on respondents' perceptions of the information provided in the video. Participants who watched the farmer version of the video were more likely to consider the video to be biased in favour of gene editing and less likely to consider the information provided in the video to be credible, than those participants who watched the scientist video.

Qualitative content analysis of text responses to the open-ended questions "What things helped you decide about the credibility?" and "What sort of things would make you think a video like this was biased/not biased?" provide some insights into how and why participants evaluated the videos as they did.

4.10. How did participants assess credibility?

4.10.1. Responses to "The video is completely or somewhat credible"

Content analysis of responses to the question "What things helped you decide about the credibility?" for the participants who had indicated either "completely credible" or "somewhat credible" for focus group 2A and 2B (n=50) revealed that 12 participants (24%) indicated that the scientific content of the video helped them decide about the credibility. Note that responses could be coded as being in more than one category. For 6 participants, this content included having seen the scientist at the end of the video (the remaining 6 saw the farmer video). For others, it was the use of scientific evidence or the presence of scientific facts. Two other participants suggested that references or citations to scientific literature should have been provided or specific research examples including details about which organisations are directly involved in this type of work.

Clarity, and the ability to understand the concepts, was another important factor for 10 participants (20%) indicating what they described as the "clear and concise" manner in which the data was presented. The use of pictures, diagrams and flow charts to make the process simpler and easy to understand also helped them decide about the credibility of the video. As one participant explained, clarity was related to competence: "I think when information is delivered in this way it shows that the person/group providing the information have a real understanding of the topic and are able to convey the message in a more simplified manner, giving it more credibility."

Explaining how the process worked was also important, with 9 participants (10%) indicating that this helped them decide about the credibility. This view differs from those who focused on 'clarity' and 'informativeness' in that the emphasis here is on the description of processes, rather than the manner in which they were explained or on the amount of information provided.

Only 8 participants (16%) indicated that the specific organisations involved in the production of the video, in particular universities, were important in assessing the credibility (however, see also Section 4.11 on bias). That the video was 'informative' (n=5, 10%), that the information presented was 'logical' (n=5, 10%), and that it was aligned with their prior knowledge about genetics acquired through study (n=5, 10%) were also factors mentioned by participants that helped them to decide that the video was completely or somewhat credible.

4.10.2. Responses to "The video is completely or somewhat uncredible or unsure"

Content analysis of responses to the question "What things helped you decide about the credibility?" for the participants who had indicated either "Neither credible/nor uncredible/don't know" for focus group 2A and 2B (n=14; see Table 1.2) showed that the most common response could be coded as "unsure" or "nothing" (n=6, 43%). Note that responses could be coded as being in more than one category. Other responses were similar to those found elsewhere.

For participants who indicated that the video was either "somewhat uncredible" or "completely uncredible" (n=6), a lack of balance (n=2), and the organisations involved (n=1) were among the factors that contributed to the participants' decisions on the credibility of the video.

4.11. How did participants assess bias?

4.11.1. Responses to "The video is completely or somewhat biased in favour of gene editing"

Content analysis of responses to the question "What sort of things would make you think a video like this was biased/not biased?" for the participants who had indicated either "Somewhat biased in favour of gene editing" or "Completely biased in favour of gene editing" for focus group 2A and 2B (n=50) revealed that the majority of participants (n=29) felt that the video was biased because it was one-sided and did not present what they considered to be disadvantages, dangers, risks, and/or downsides. Note that responses could be coded as being in more than one category. As one participant noted: "If it highlighted the benefits of gene editing in an impartial way, while also acknowledging that there are risks and moral/ethic [sic] questions regarding the technology. It is not a one-way argument, and both sides of the debate should be presented equally and impartially." However as another noted, this type of bias did not necessarily affect perceptions of credibility: "No critical views aired in the video … (I am not suggesting I have a problem with it, this is just an observation)."

Other factors were identified far less frequently by participants. The involvement of the organisations in the development of the video (n=4) and lack of diverse perspectives (e.g., from consumers and animal welfare advocates, n=3) were also mentioned. Some participants (n=3) acknowledged that some bias is inevitable when trying to explain a process such as gene editing: "I think no matter how hard we try to be unbiased we all come out with a bit of bias in whatever we do. As this video tries to explain what gene editing can do, it inadvertently shows a slight bias toward it."

4.11.2. The video is neutral or balanced

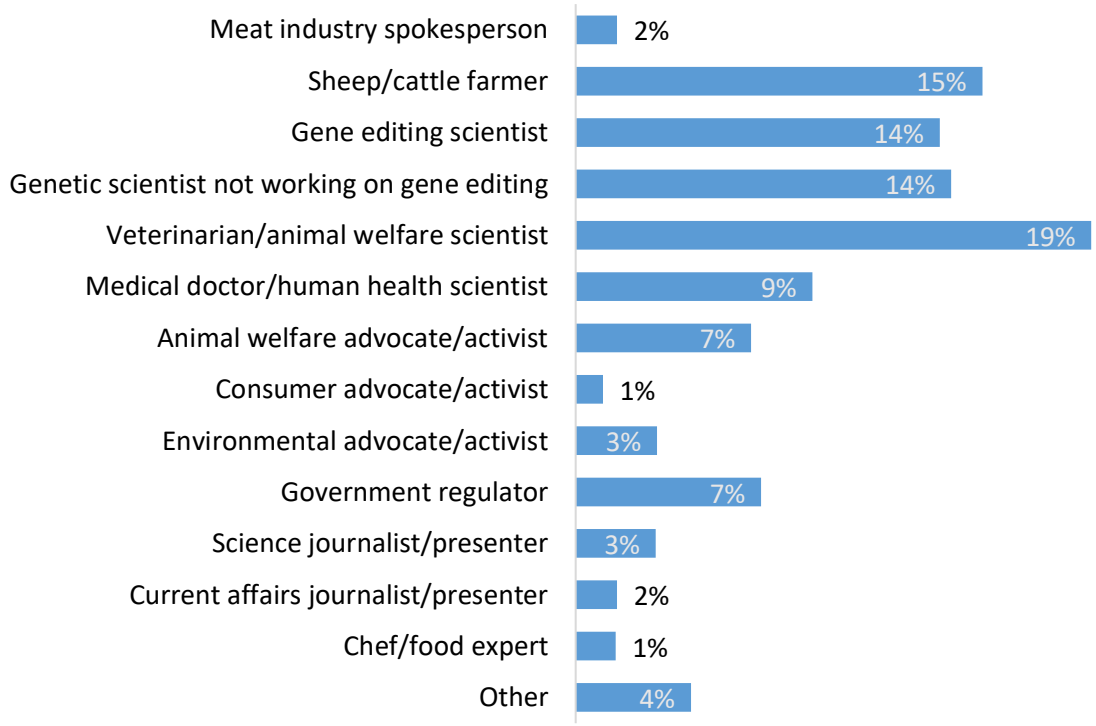
No participants thought that the video was biased against gene editing. The video was viewed as neutral or balanced by 26 participants (see Table 1.4). Seven participants described the video in ways that were coded as 'factual,' stating for example that "It just provides facts and information that people may or may not have heard of." Other participants described the video as 'neutral' (n=3) and that it was mainly an 'explanation' (n=3). One participant mentioned that the basis of the video was "getting your views about the use of gene editing" which showed that it was balanced. Six participants answered the question "What sort of things would make you think a video like this was biased/not biased?" literally, and suggested things that *would* make them interpret the video as biased or not biased, instead of things that *did*, for example: "Biased if only one side (only benefits or only disadvantages) was talked about/argued. Not biased if experts provided a neutral discussion of both advantages and disadvantages."

4.12. Who do community members want to hear from?

Finally, we asked survey respondents from who they would like to hear when deciding if and how gene editing should be used in meat production. Because it was clear from the focus groups that participants were seeking diverse perspectives, this question was not an attempt to determine the ideal messenger to communicate about gene editing, but rather to identify which perspectives and messengers were important to participants. The survey results corroborate the qualitative results from the community focus group that scientists are well regarded; however it is clear that the type of scientist matters. Nearly 20% of survey respondents reported that they would most want to hear from veterinarians or animal welfare scientists, followed by sheep/cattle farmers (15%), gene editing scientists (15%), or genetic scientists who are not working on gene editing (15%) (see Figure 33).

Notably, meat industry spokespersons were among those perspectives that community members were least interested in hearing (2%), along with chefs/food experts (1%), consumer advocates/activists (1%), and current affairs journalists/presenters (2%). Again, it is important to emphasise that this question does not provide results that are interchangeable with the outcomes reported in Section 4.8 where the emphasis was on trust to develop and regulate gene editing in a way that aligns with the participants' values. Although participants may not trust commercial producers to develop and regulate the use of gene editing in livestock production, they are considered important stakeholders by the community.

Figure 33: Percentage of community survey respondents who gave each response to the question, "Whose perspective would you MOST want to hear and tend to trust when deciding if and how gene editing should be used in meat production?" (n=2146)



5. Understanding producer and industry attitudes toward gene editing

5.1. Methods for collecting producer and industry attitudes toward gene editing

Producer and industry views on the prospective use of gene editing in beef and sheepmeat production were primarily collected via semi-structured interviews with Australian beef and sheep meat producers, related stakeholders, and experts. The aims of the producer interviews were to gain a snapshot of producer and industry views on the prospective use of gene editing in beef and sheepmeat production at the current, relatively early stage of the technology's development. Producers were asked open- and closed-ended questions about their views on gene editing, its various prospective applications in beef and sheepmeat production, and the social and regulatory context in which it might be applied. Producers were recruited both using industry networks and announcements, and via a panel recruiter.

Due to the ongoing COVID-19 pandemic and associated risks of meeting face-to-face, telephone interviews were conducted. To provide ample opportunities for producers to participate in the research, a mixed quantitative and qualitative survey was also made available to producers who were not able to participate in telephone interviews. This survey had the same aims and addressed the same topics as the producer interviews.

The interviews were digitally recorded and transcribed. Qualitative interview and survey responses were coded using methods similar to open coding (Strauss and Corbin 1990) using the generic inductive qualitative model (Hood 2007; Maxwell 2012). Quantitative data from the interviews and survey were cleaned to remove incomplete responses, following standard research practices.

5.2. Participants in the producer interviews and survey

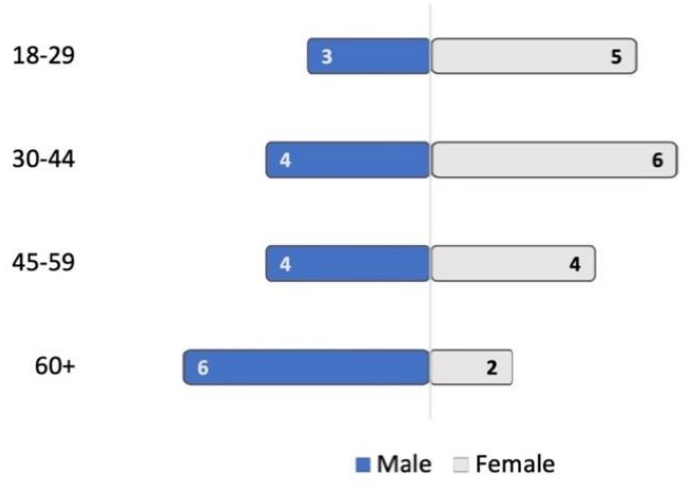
Participants for the producer interviews and survey were initially recruited via MLA's *Friday Feedback* newsletter on 11 September 2020, as well as through invitations sent to several relevant state and national organisations for distribution to their members. However, the response to these invitations was low, necessitating the use of a professional recruitment company to recruit participants for the producer interviews. Despite multiple recruitment and data collection strategies, the sample of producer respondents in this study remains small. As a result, the data collected from producers does not represent the views of the wider producer community but may provide some helpful pointers that can be considered when shaping strategies for engaging producers with regard to gene editing in livestock. A summary of key characteristics of producer participants is provided below.

In total, 33 completed surveys and a further 5 incomplete surveys (>50% completed) were collected. Of these, 18 were submitted by producers involved in the beef industry, 6 by people involved in the sheepmeat industry, and 14 involved in both industries. All of the sheepmeat producers (n=6) and most of the joint beef and sheepmeat producers (n=9) produced both wool and prime lamb. Most of the producers ran merino or merino crosses (n=17), while nine producers raised meat sheep breeds, such as Suffolk, Poll Dorset, or white Suffolk. Only three producers bred rams for their own commercial flocks or for sale, while the overwhelming majority (n=16) ran a commercial flock and bought rams. Most of the beef and joint beef and sheepmeat producers who participated in the survey ran cow/calf

enterprises (n=20) producing feeder steers (n=15), store weaners (n=9), and vealers (n=3) or trade enterprises (n=20), while only 9 survey participants operated stud enterprises.

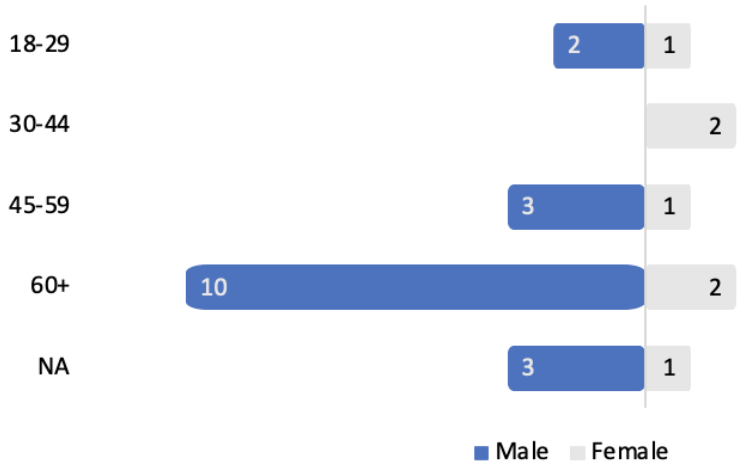
Demographically, survey participants were balanced between female and male respondents, with older male respondents somewhat overrepresented in the sample (see Figure 34). South Australian producers (n=13) are also overrepresented in the sample, compared with producers from New South Wales (n=6), Victoria (n=6), Queensland (n=5), and Western Australia (n=2). One producer did not provide information on their location.

Figure 34: Distribution of age and gender of producer survey respondents (n=34); an additional 4 respondents preferred not to disclose their gender or did not provide a response



In total, 26 producers were interviewed for the study, of which 12 were beef producers, 3 were sheepmeat producers, and 10 produced a mixture of beef and sheepmeat. Sixteen producers classified their operations as commercial enterprises, and 7 as studs or joint stud and commercial enterprises. The sample includes a good mixture of small (n=8), medium (n=10), and large (n=8) farms as classified by the operators. As with the producer survey, the interview sample is also skewed toward male producers 60 years of age and above (see Figure 35).

Figure 35: Distribution of age and gender of producer interviewees (n=26); one interview conducted with a farmer couple is omitted from the figure

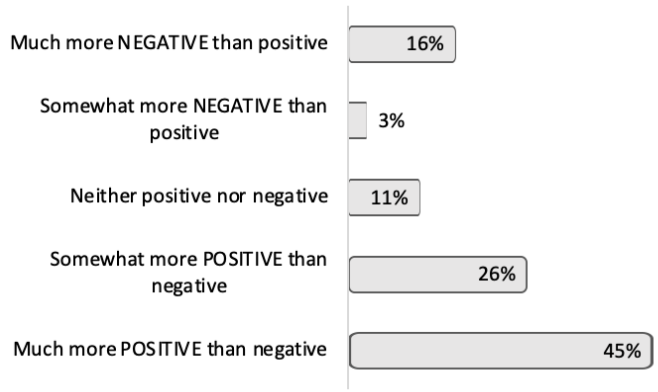


5.3. Producer attitudes to gene editing in beef and sheepmeat production

As a smaller phase within this project, we sought to assess and understand Australian producers' attitudes toward the prospective use of gene editing in the beef and sheepmeat industry. This phase of the research was particularly aimed at producing data that allowed us to compare producers' views with those found in the community phases with particular focus on gene editing, given MLA already has considerable engagement with producers with regard to genetics and breeding values more generally.

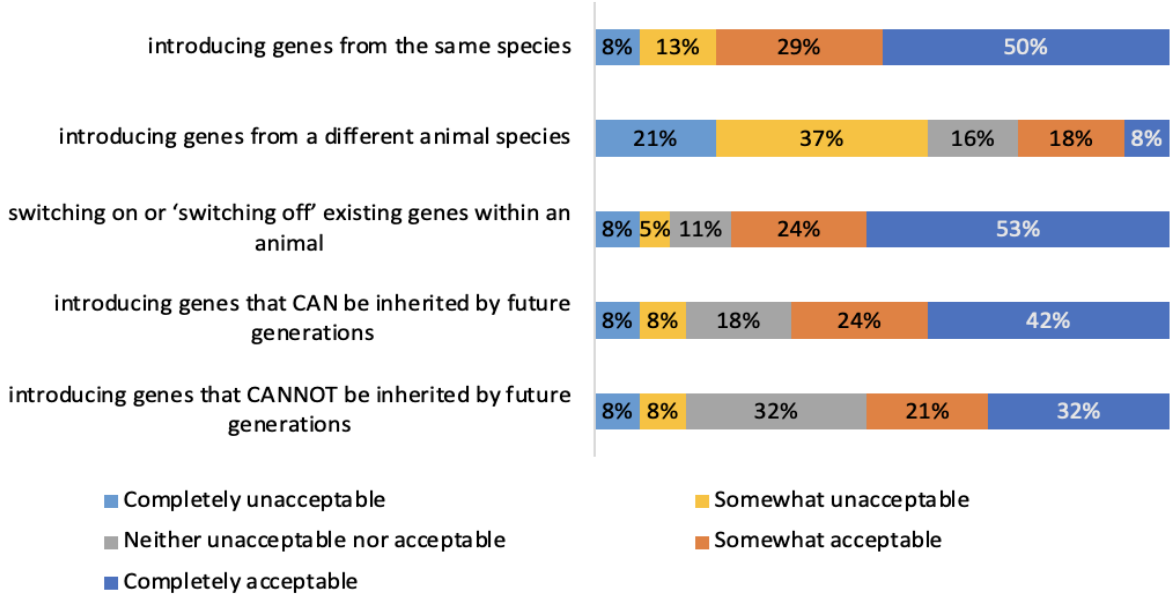
We first asked producers to complete a survey which asked respondents to indicate how they feel about the technology related to gene editing in general, as well as their attitudes toward specific prospective applications. The response rate was somewhat small but did permit us to assess general trends. Overall, the majority of the surveyed producers had more positive than negative feelings about gene editing. Nearly half of the survey respondents had much more positive than negative feelings about gene editing (45%, n=38) and 26% were somewhat more positive than negative (Figure 36). However, those participants whose feelings were more negative tended to have much more negative than positive feelings: 16% were much more negative than positive, compared with 3% who were somewhat more negative than positive. The remainder of survey respondents (11%) were neither positive nor negative toward gene editing. We then used interviews with select producers who volunteered following the survey to further investigate these responses, and we include this qualitative data selectively below to help shed light on the general trends recorded in the survey.

Figure 36: Percentage of surveyed producers who rated their feelings about gene editing in each of the five categories in response to the question "In general, do you feel more positive or more negative about gene editing?" (n=38)



With regard to particular types of gene editing, producers indicated that most types would be acceptable to them, including the use of gene editing technologies to switch on or off existing genes, to introduce genes from the same species, and to make heritable and non-heritable changes to an animal, with non-heritable changes being less preferred than heritable ones (see Figure 37). In contrast, the introduction of genes from a different animal species was considered to be unacceptable by more than half of the survey respondents, parallel to findings from the community study. From the producer interviews, we see that this latter view tends to be associated with those producers who have general concerns about needing to place limits on this sort of technology and not "playing God" or "messing with nature." As a result, they see using genes from other species as beyond what is possible in nature, or done by producers and breeders via selective breeding, and hence are cautious or resistant to these uses of gene editing.

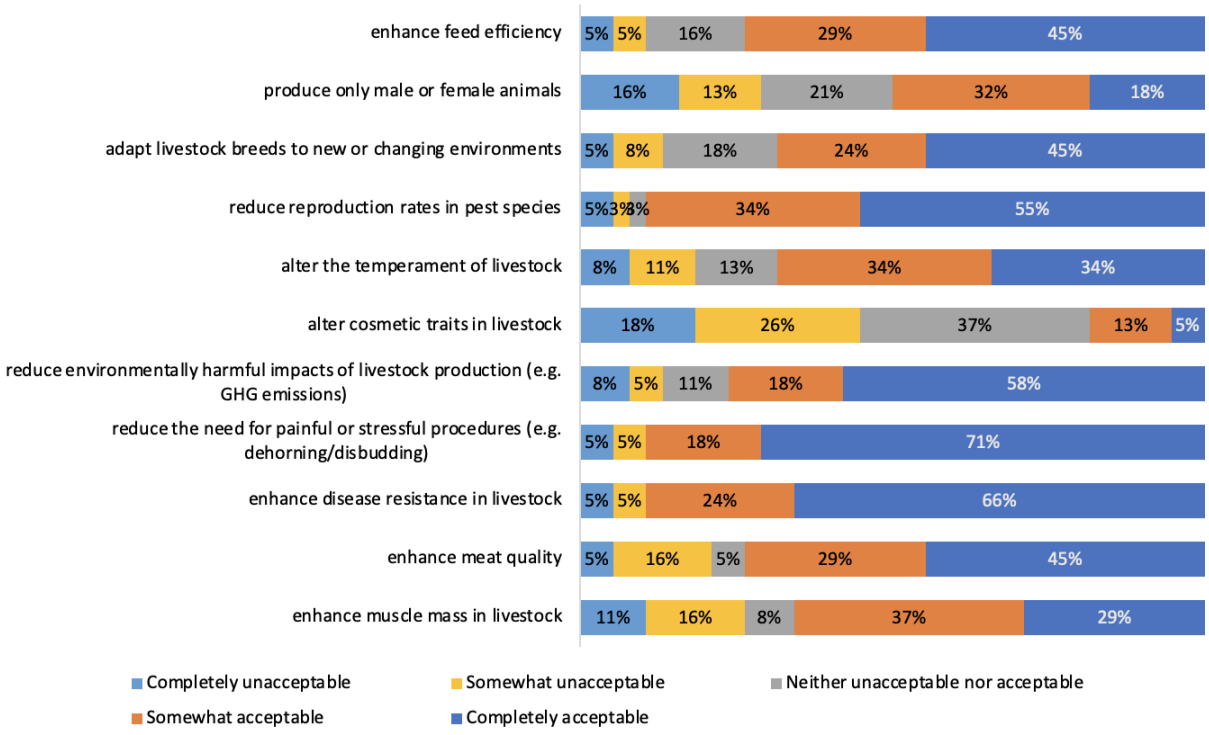
Figure 37: Percentage of survey respondents (n=38) who rated the acceptability of each type of gene editing applications in response to the question: "In your view, how acceptable or unacceptable is it to modify the genes of livestock by..."



An overwhelming majority of surveyed beef and sheepmeat producers also found most of the proposed applications of gene editing to be acceptable (see Figure 38). Two survey respondents indicated that gene editing for livestock production is unacceptable no matter how it is used, and one participant felt gene editing in livestock production is always acceptable. Applications that targeted animal health and welfare, such as reducing the need for painful or stressful procedures or enhancing disease resistance in livestock, were most frequently rated as being completely acceptable, and these views tended to parallel the findings in the community study. As one producer put it in the interviews, "I think all beef producers you know by nature have a focus on animal welfare and if you can increase animal welfare without decreasing productivity you know, that's the golden–or Holy Grail." Using gene editing to reduce the reproduction rates in pest species was also viewed as acceptable by the majority of producer respondents.

However, the use of gene editing to alter cosmetic traits was viewed as either unacceptable or neutral by most producer survey respondents, again in parallel to the community respondents. Producers had much more positive views on altering temperament particularly in comparison to the community responses. Producers in the interviews stressed that they already tended to try to use low-tech means (such as crossbreeding and specific selection processes) to produce animals that they described as less "bossy" or "rogue," and saw altering temperament using gene editing as a more precise and efficient way of doing something that already was a goal in their standard practices. Producers also strongly supported gene editing which has positive environmental effects, and in the interviews often noted their concerns about needing to intensify production in a sustainable manner particularly due to climate change. Producers also tended to support gene editing for enhancement of meat quality.

Figure 38: Percentage of producer survey respondents (n=38) who ranted the ethical acceptability of various applications of gene editing in livestock production, in response to the question: "How ethically acceptable or unacceptable do you feel it is to use gene editing to..."



6. Conclusion

This research analysed community and producer attitudes toward gene editing, its prospective use in beef and sheepmeat production, and the drivers of those views. The study identified several existing community discourses on gene editing, as well as specific concerns about the proposed applications of gene editing in livestock production. On the basis of these findings, a set of best practice guidelines have been developed which will assist the red meat industry in engaging members of the Australian community on the topic of gene editing.

6.1. Key findings

(1) Following a Q-Methodology approach, the study identified five existing discourses on gene editing within the Australian community. While one of these discourses is generally optimistic about the potential that gene editing might solve perceived issues within the food system, the other four are either conditionally supportive, or opposed to the use of gene editing in livestock production.

(2) Attitudes toward the use of gene editing in beef and sheepmeat production are likely to be influenced by existing attitudes toward livestock production, as well as to science and novel technologies more generally.

(3) Applications of gene editing that benefit animal welfare or have other clear benefits to society are more likely to be accepted by members of the Australian community than are applications that primarily aim to improve production efficiencies and outputs. Applications of gene editing that do not have a clearly identifiable purpose that benefits animal welfare, the environment, or society are unlikely to be accepted by the community.

(4) Community attitudes are relatively insensitive to differences in the types of gene editing, such as between heritable and non-heritable changes, or 'switching off or on' genes versus introducing genetic material from other animals. A notable exception is the introduction of genetic material from an animal of a different species, which is largely rejected.

(5) Producer attitudes toward gene editing are generally more positive than they are negative. Producers share many of the general and specific concerns about gene editing and its application in red meat production that were raised by members of the community. In particular, producers emphasise the need to prioritise animal welfare in the application of gene editing. However, producers had much more positive views about altering temperament particularly in comparison to the community responses.

(6) Overall, the most trusted stakeholders in gene editing in livestock are scientists, but with caveats. Firstly, funding and motivations matter for all stakeholders. Trust is lower for scientists/experts where either funding or research interests are viewed as being aligned with promoting gene editing, rather than scientists that are motivated to improve animal welfare. Secondly, different actors are trusted to do different things, so that although producers may not be trusted to regulate the use of gene editing in livestock (because of their potential vested interests), their expertise and experience makes their perspectives relevant to the community who would like to hear these views.

(7) The discourses identified in this research will facilitate the development of tailored messages addressing areas of concern for the community. Including diverse stakeholder voices speaking on a range of issues will be vital for effective community engagement that will maintain SLO.

6.2. Benefits to industry

This study has generated rich data on community hopes for and concerns about gene editing and thus has generated a variety of benefits to the red meat industry, which in turn have practical implications, as follows:

(1) The study provides more understanding of the reactions and reception that might result should gene editing be trialled or used in the Australian livestock industry. As is clear from the data, although there are diverse views, particularly among community members, there is widespread support for applications of gene editing that have health or welfare benefits for the animals themselves. Hence it is likely that these sorts of applications should be considered for investment and implementation first, prior to trialling other types of applications of gene editing, assuming that some of these sorts of applications have sufficient scientific support.

(2) The findings give a window more generally into some of Australians' concerns about red meat production, and particularly trade-offs between animal welfare, production efficiency, and environmental issues. Views at the intersection of these factors are complex, and it is likely that our findings have implications well beyond gene editing into other uses of technologies or novel production practices, including various genetic strategies. MLA should consider implementing ongoing strategies to engage the public around these issues (see the engagement strategy below), particularly given increasing attention to the effects of red meat production on the environment and related initiatives to reduce red meat consumption.

(3) The data support the need for more proactive initiatives to engage stakeholders in spaces associated with technology development and best practices in the red meat industry, ideally while such technologies are under consideration and in the earliest stages of research. Many community members had low levels of self-reported knowledge and evidenced various gaps in their understanding of production practices which points to the need to better engage the broad public, even if there will be a vocal minority which may raise concerns about various practices as a result of greater transparency.

(4) Given that the organisations that were least trusted included industry organisations, businesses involved in gene editing, and commercial producers, there is the need for the industry to involve a range of experts in any discussions or engagement about gene editing with the community, to actively engage in processes that promote oversight and accountability together with actively supporting formal regulation and/or self-regulation where relevant, and to motivate particular applications in terms of clear benefits that are likely to be socially acceptable based on the results above.

(5) The study also suggests that there will be difficulties in balancing community concerns about the pursuit of industry profitability, including types of gene editing that may assist with innovations and improvements in livestock production, with what the community views as the most ethical and trustworthy decisions about using such technologies. Although there is strong support for those producers who are viewed as 'farmers,' there are broader concerns about larger-scale and corporate farms and the agricultural industry at large, and there is considerable work to do in this space in order to improve the basis for the red meat industry's SLO.

6.3. Future research and recommendations

6.3.1. Strategy for community engagement

Strategic communication is defined as communicating *purposefully* to advance a mission (Hallahan et al. 2007) and involves engaging in deliberate communication practice on behalf of organisations. Strategic communication involves determining overarching goals for specific audiences, and then drawing on explicit or implicit theory to identify objectives that might be expected to lead to the desired goal (Besley et al. 2019). Overall, there is a lack of discussion about strategic communication applied to scientific issues in the research literature and little evaluation of communications strategies that could be used to inform the development of an effective engagement strategy about gene editing in the livestock industry in Australia. Hence, as we have noted earlier, the proposed recommendations draw on a range of approaches that have been used in engagement about complex issues that have science at their core. Based on these approaches, we have developed a number of guiding principles to develop the recommendations presented, and these have also informed this research:

- engagement strategies need to have a clear goal;
- an understanding of the audiences or communities that will be engaged is vital, and this understanding goes beyond demographics to exploring values and concerns;
- understanding audience perceptions of key stakeholders is vital to deciding which actors are trusted to both manage and communicate about issues; and
- message attributes (i.e., the *what* and *how*) are determined by both the engagement goals and the audiences.

6.3.2. Goals for community engagement

Strategic goals for community engagement should relate to the specific behaviours that an organisation would like to see result from engagement. For some issues, these behaviours may be obvious, for example social distancing related to COVID-19. However, in some cases behavioural goals may relate to the willingness to accept a decision (i.e., a target audience engaging in behavioural trust by making itself vulnerable or accepting the legitimacy of a controversial decision) (Besley 2020). Non-opposition is also a behaviour, as is the new or continued granting of SLO (though it is often difficult to know when this actually has implicitly occurred). Research suggests that scientists or groups or scientists rarely think about communication goals in terms of behaviours (including pseudo-behaviours such as support or acceptance) (Besley et al. 2021) and yet these are fundamental to effective engagement strategies.

Within this research, we have articulated the goal as being for MLA to maintain its SLO. Note that this goal is distinct from community acceptance of the use of gene editing in the livestock industry. It will be important for MLA to determine what successful engagement will look like. However, the recommendations below have been determined with the goal of MLA being seen as a trustworthy and trusted operator in the research, development, and deployment of genetic and other types of technologies in the Australian cattle industry.

6.3.3. Communication objectives and tactics

Communication objectives relate to targets that may lead to the desired behaviours, for instance changes in knowledge, interests, various trust-related beliefs, beliefs about efficacy or norms, and so on. Tactics relate to the choices and tools that are available to communicators during engagement (Besley et al. 2019). It is beyond the scope of this research to propose specific tactics to achieve communication objectives; however we make suggestions for the types of tools that may be used in engagement. Tactics might also include choices about how to prioritise resources before, during, and after communication to enable important processes such as follow-up research and evaluation on audiences and their attitudes and behaviours.

6.3.4. Audiences, messages, and message attributes

In Table 4, we summarise the key audiences for community engagement based on the discourses identified in this research. Recommendations are also made for key messages and message attributes, as well as consideration of tactics that may be used to achieve communication objectives with these audiences. This matrix demonstrates that several activities may be used for more than one audience; however there should still be adjustments at the tactical level such as message framing and the use of particular voices to ensure that specific audience needs are being met. It is also important that an objective for one audience does not have a negative effect on another. Currently this matrix is very much aimed at non-producer audiences, and as such it is important to frame communication away from productivity and profitability. However, we acknowledge this framing may not be appropriate for producers and other stakeholders in the industry, and so there may be challenges with managing internal and external communications.

Table 4: Engagement strategy matrix with engagement objective (i.e., behaviours that the engagement will encourage), key messages, and high-level tactics that may be used to achieve the engagement objective, for each of the discourses identified by the Q-sorts

Discourse and key features	Engagement objectives	Message attributes	Tactics
1. Morally neutral and potentially useful (15%) • Judge the technology on its applications • See problems with current red meat production (which gene editing might fix), but not opposed to red meat production • Seek ethical/social benefits • Support regulation • Generally trusting of science • Would serve gene edited meat to their families	• Trust MLA's investment in this technology (to do no harm to animals) • Feel like concerns are heard and shared • Trust regulation • Trust science • Purchase and consume red meat • Purchase and consume gene-edited meat • Continue to support red meat production	• MLA wants social and ethical benefits too • MLA cares about food safety • MLA won't support projects with negative animal welfare outcomes • Acknowledge that there are issues in red meat production with a range of solutions of which this is one • Be open about research goals • Support regulation • Discuss the science openly and talk about risks	• Open declaration about investment in projects and details on their purposes • Clear review processes for gene editing investments • Include diverse voices in communication (e.g., website) • Be proactive in engagement (reach out, and don't just provide information) • Ongoing engagement activities and processes
2. Interfering without understanding (9%) • Worries about unknown/long term • Sees interfering with complex, natural systems as risky • Scientists do not or cannot understand • Concerned about all applications • Sees gene edited meat as unsafe • Benefits will not ever outweigh risks	• Trust MLA's investment in this tech (to do no harm *in general*) • Feel like concerns are heard • Trust regulation • Trust science • Purchase and consume red meat • Continue to support red meat production	• MLA cares about food safety • MLA won't support projects with negative animal welfare • Be open about research goals • Support regulation • Discuss the science openly and talk about risks	• Open declaration about investment in projects and details on their purposes • Clear review processes for gene editing investments • Include diverse voices in communication (e.g., website)

	• Non-opposition of technology		• Be proactive in engagement (reach out, and don't just provide information) • Ongoing engagement activities and processes
3**. Prioritise animal rights and welfare (3%)** • See animals as having intrinsic rights and integrity • Ambivalent about gene technology • Oppose meat production • Oppose gene technology to increase productivity or profitability • Distrust the meat industry (and industry-funded research) • Accept gene technology in other applications • Trust scientists • Unconcerned about effects in human health (as don't consume meat)	• Trust MLA's investment in this technology (to uphold high standards of welfare) • Feel like concerns are heard • Trust regulation • Continue to trust scientists • Non-opposition of red-meat production and support SLO	• MLA won't support projects with negative animal welfare • MLA won't support projects with a negative impact on other animals • Be open about research investment • Support regulation • Discuss the science openly and talk about risks	• Declaration about investment in projects and details on their purposes • Clear review processes for gene editing investments • Include diverse voices in communication (e.g., website) • Be proactive in engagement (reach out, and don't just provide information) • Ongoing engagement activities and processes
4. I just don't know (4%) • Genuinely undecided • Concerned about a range of issues	• Trust MLA's investment in this tech (to do no harm *in general*) • Feel like questions will be answered • Trust regulation • Trust scientists	• MLA wants social and ethical benefits too • MLA cares about food safety • MLA won't support projects with negative animal welfare • Be open about research goals • Support regulation	• Declaration about investment in projects and details on their purposes • Clear review processes for gene editing investments

	• Non-opposition of red-meat production and support SLO	• Discuss the science openly and talk about risks	• Include diverse voices in communication (e.g., website) • Be proactive in engagement (reach out, and don't just provide information) • Ongoing engagement activities and processes
5. Open for abuse (10%) • Concerned that pursuit of profits will drive misuse • Perceive profitability as motivation for the tech • Want regulation, legislation, and oversight (although sceptical about whether these will work) • Mistrust several actors • Trust scientists to produce credible research	• Trust MLA's investment in this tech (to do no harm *in general*) • Trust regulation • Continue to trust scientists • Non-opposition of red-meat production and support SLO	• MLA wants social and ethical benefits too • MLA cares about food safety • MLA won't support projects with negative animal welfare • Acknowledge that there are issues in red meat production with a range of solutions of which this is one • Open about research goals • Support regulation • Discuss the science openly and talk about risks	• Declaration about investment in projects and details on their purposes • Clear review processes for gene editing investments • Include diverse voices in communication (e.g., website) • Be proactive in engagement (reach out, and don't just provide information) • Ongoing engagement activities and processes

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8. Appendices

8.1. Appendix A: Q-factor extraction

Table 5: Factor eigenvalue and variance, including statistical criteria for retaining 5 factors.

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Eigenvalues	21.732	14.435	5.293	4.218	3.859
% Explained Variance	22	15	5	4	4
Cumulative % Expln Var	22	37	42	47	51
Humphrey's Rule	0.72804	0.58921	0.38549	0.36658	0.27627
Standard Error	0.10102	0.10102	0.10102	0.10102	0.10102

Parallel Analysis

Factor	Actual EV	Mean EV for Random Data	95th Percentile EV for Random Data
Factor 1	21.73161	5.98297	6.45054
Factor 2	14.43459	5.51361	5.84308
Factor 3	5.29331	5.17035	5.44994
Factor 4	4.21814	4.88049*	5.1218
Factor 5	3.85932	4.62299*	4.85584

* The unrotated Eigenvalues for Discourses 4 and 5 are lower than the 95th percentile EV derived from a parallel analysis using random data. This indicates that these discourses could be excluded from the analysis on the basis that they have a greater than 5% chance of reflecting random patterns in the data rather than meaningful discourses. They have been retained, however, because we judged that they reflect theoretically significant views based on the representative Q-sorts and accompanying qualitative responses

8.2. Appendix B: Community survey design

Screening questions:

Q1. What is your current age (select appropriate age bracket)?

- 18–24
- 25–29
- 30–34
- 35–39
- 40–44
- 45–49
- 50–54
- 55–59
- 60–64
- 65+

Q2. What is your gender? Male / Female / Prefer to self-describe

Q3. What is your postcode?

Q4. Which ONE of the following best describes your current diet?

- Omnivore (consumes both plant and animal-based foods)
- Lacto-vegetarian (consumes dairy, but no meat or eggs)
- Ovo-vegetarian (consumes eggs, but no meat or dairy)
- Lacto-ovo vegetarian (consumes dairy and eggs, but no meat)
- Pescatarian (consumes fish, but no red meat)
- Vegan (consumes no food of animal origins)
- Flexitarian (consumes a primarily vegetarian diet, but occasionally eats fish or meat)
- Other (please specify)

Q5. What best describes your ethnic heritage (please select all that apply)?

- Australian
- Aboriginal or Torres Strait Islander
- North-West European (pop-up: UK, Ireland, Germany, France, Swiss, Scandinavia, Benelux, etc.)
- Southern or Eastern European (pop-up: Spain, Portugal, Italy, Greece, Poland, Russian, Hungarian, Slavic, Baltic, etc.)
- North-East Asian (pop-up: Chinese, Japanese, Korean, etc.)
- South-East Asian (pop-up: Thai, Vietnamese, Indonesian, Filipino)
- Southern Asian (pop-up: Indian, Sri Lankan, Nepalese, Bengali, Punjabi, Pakistani, etc.)
- Central Asian (pop-up: Armenian, Georgian, Afghan, etc.)
- Polynesian, Pacific Islander, Maori
- North African or Middle Eastern
- Sub Saharan African
- North American
- South or Central American or Caribbean Islander
- Other (please specify): TEXTBOX
- I prefer not to say

Q6. Do you affiliate yourself with any of the following religions?

Christianity
Islam
Buddhism
Hinduism
Judaism
Other (please specify)
No religious affiliation
Prefer not to say

Survey questions:

Q7. On average, how often do you eat the following… Beef/Lamb/Mutton/Chicken/Other Meat

Almost every day or every day
Between three and five times a week
Between one and three times a week
Less than once a week
Don't eat this meat

Q7b. What are your main reasons not to meat/beef/lamb/mutton (select all that apply)?

religious reasons
I don't like the taste
Health reasons
Animal welfare concerns
Environmental concerns
Other (please specify)

Attitudes toward meat production:

Q8. On a scale of 1–7, where 1 is 'completely disagree' and 7 is 'completely agree', please indicate your level of agreement with the following statements:

People have a right to eat meat.
Australian beef, lamb & mutton producers deserve better prices and purchase conditions.
Long-distance transport of live cattle and sheep for meat production should continue.
The standard of animal welfare on Australian farms needs to be improved.
Increased regulation of the treatment of cattle and sheep used for meat production is needed.
The welfare of cattle and sheep kept on feedlots is lower than that of free-range cattle and sheep.
It is wrong to raise cattle and sheep for meat production.

Anthropomorphism

Q9: On a scale from 0 to 10, where 0 is 'Not at all' and 10 is 'Very much', please indicate to what extent you think these statements are true:

The average cow and sheep has thoughts of its own
The average cow and sheep has intentions
The average cow and sheep has consciousness

The average cow and sheep experiences emotions
The average cow and sheep has free will
The average cow and sheep is strong
The average cow and sheep is active

Attitudes toward technology:

Q10. On a scale of 0 – 10, where zero means 'strongly disagree' and 10 means 'strongly agree' how much do you agree or disagree with the following statements about science and technology:

Science and technology can solve most problems faced by human beings
It is important for governments to regulate new technologies
Scientific advances tend to benefit the rich more than they benefit the poor.
Technological change happens too fast for me to keep up with
New technologies excite me more than they concern me

Awareness of gene editing:

Q11. Which of the options below best describe your current awareness of gene editing?

Never heard of
Have heard of, but know little or nothing about
Know enough about it that I could explain it to a friend
Can't say/ don't know

Gene editing

The following questions are about what you think and feel about the possibility that gene editing will be used in livestock production in Australia. Please read the description of gene editing below and reply to the following questions.

Gene editing is a laboratory technique where targeted changes are intentionally made to the genetic code (DNA) of an organism, such as plants and animals. This is done in order to change the traits of the organism by either removing, adding, or exchanging genes or parts of genes.

One way that gene editing could be used is to speed up changes in animal traits that could otherwise be achieved through traditional selective breeding, by introducing the genetic information from another breed of the same species or by 'turning on' or 'turning off' existing genes within a breed. Edited genes are potentially inherited by the next generation and can be used to pass on the trait throughout a herd/flock.

Please read each of the following statements.

Q12. On a scale of 1 to 9 where 1 is completely DISAGREE and 9 is completely AGREE, how much does the following view align with your thinking about the use of gene editing in beef, lamb & mutton production?

Discourse 1: As long as gene editing is safe and does not harm the animals, then I don't see any reason why gene editing shouldn't be used. It would be great if gene editing can improve the sustainability and standard of animal welfare in Australian beef, lamb & mutton

production. If gene editing also helps producers meet the growing demand for meat, then that's a good thing.

Discourse 2: I am worried that scientists don't know enough about the long-term consequences of gene editing cattle and sheep and would not support any use of gene editing in livestock production until I see all the facts. Altering nature is always risky and I would prefer that producers try to achieve the same changes using more natural methods.

Discourse 3: I think it is wrong to raise cattle and sheep for meat production but would support the use of gene editing to improve the health and wellbeing of animals raised for meat. However, I would be more comfortable with using gene editing in crops or to produce alternatives to meat. I think the meat industry is mostly interested in creating the perfect meat producing animal.

Discourse 4: I don't think that that gene editing can address the problems I care about in the food system and am worried that gene editing will negatively affect ecosystems and the diversity that exists in nature. However, I would be open to using gene editing in meat production if the benefits to society do outweigh the risks.

Discourse 5: Most of the time, gene editing is just about profit. I am more worried that unscrupulous people might misuse gene editing for profit than that scientists don't know the real risks of gene editing. As a society, we need to carefully consider how decisions about gene editing should be made and who should be involved.

Q13. On a scale of 1 to 9 where 1 is completely DISAGREE and 9 is completely AGREE, how much does each of the following statements align with your thinking about the use of gene editing in beef, lamb & mutton production:

- It is a problem that cattle and sheep cannot consent to gene editing.
- I wouldn't want meat to look or taste different as a result of gene editing.
- Gene editing cattle and sheep will make something natural into something unnatural.
- When scientists edit genes, they're playing God.
- When it comes to gene editing, cattle and sheep should be treated equally to humans.
- Gene editing of cattle and sheep would result in less natural diversity.
- I just hate the thought of the whole process of gene editing.
- Gene editing should not be used to improve the economic conditions of meat producers.
- I'd be happy to serve gene edited meat to my family.
- We need to use gene editing to modify cattle and sheep to be compatible with new or changing environments.

Q14. In a few words or sentences, please summarise your views on the use of gene editing in beef, lamb & mutton production:

Applications of gene editing in beef, lamb & mutton production

The following questions are about how ethically acceptable or unacceptable you feel it is to use gene editing to pursue different goals for livestock production.

Q15. How ethically acceptable or unacceptable do you feel it is to use gene editing to… [
enhance muscle mass in livestock to increase the amount of meat produced per animal
enhance the eating quality of meat
make meat healthier to consume
make livestock more resistant to disease
reduce the need for livestock to undergo painful or stressful procedures
reduce negative environmental impacts of livestock production
alter coat colour and thickness to increase the heat tolerance of cattle
alter the temperament of livestock to prevent injuries for animals and workers
reduce the ability of pests that affect livestock to reproduce
adapt livestock to new and changing environments
increase the birth rate of male animals to produce more meat per animal and reduce waste
enhance the ability of cattle and sheep to digest lower quality feed

Q15a. In your view, is there any use of gene editing in livestock production that would be ACCEPTABLE?
No, gene editing for livestock production is UNACCEPTABLE no matter how it is used
Yes, gene editing for livestock production is ACCEPTABLE if it is used to... (please write)

Q15b. In your view, is there any use of gene editing in livestock production that would be UNACCEPTABLE?
No, gene editing for livestock production is ACCEPTABLE no matter how it is used
Yes, gene editing for livestock production is UNACCEPTABLE if it is used to... (please write)

Q16. Using a scale of 1–7, where 1 is completely unacceptable and 7 is completely acceptable, please indicate how acceptable you feel it would be to alter the genes of cattle or sheep by…
introducing genetic information from an animal of the same species
introducing genetic information from an animal of a different species
switching on or 'switching off' existing genes within an animal
introducing genes that CAN be inherited by future generations
introducing genes that CANNOT be inherited by future generations

Risks

Q17. In general, how concerned or unconcerned are you that gene editing in livestock production presents risks for…
Human health
The welfare of livestock
Rare livestock breeds
Native wildlife
The environment
Red meat producers

Q18. In a few words or sentences, please summarise how you feel about the potential risks of using gene editing in beef, lamb & mutton production.

Social context

The next questions are about how you feel about various types of people and organisations that are involved in gene editing.

Q19. On a scale of 1–7, where 1 is 'Completely disagree' and 7 is 'Completely agree', please indicate your level of agreement with the following statements

- Australian farmers are poor custodians of the land.
- I trust products from Australian-owned farms more than farms that are foreign-owned.
- Adopting the latest technologies helps livestock farmers to produce more sustainable meat.
- Farmers know what is best for their livestock.
- Smaller farms offer greater levels of care for livestock than do larger farms.
- Compared with family farms, corporate-owned farms have lower standards of animal welfare.
- Scientists can accurately predict the outcomes of changes made through gene editing in livestock.
- Scientists and breeding companies have motivations that I agree with.
- The federal government of Australia will appropriately regulate the use of gene editing for livestock production.
- The meat industry will appropriately self-regulate the use of gene editing for livestock production.

Q20. Whose perspective would you MOST want to hear and tend to trust when deciding if and how gene editing should be used in meat production?

- Meat industry spokesperson
- Sheep/cattle farmer
- Gene editing scientist
- Genetic scientist not working on gene editing
- Veterinarian/animal welfare scientist
- Medical doctor/human health scientist
- Animal welfare advocate/activist
- Consumer advocate/activist
- Environmental advocate/activist
- Government regulator
- Science journalist/presenter
- Current affairs journalist/presenter
- Chef/food expert
- Other: TEXTBOX

Demographics

Q21. What was the last level of formal education that you attained?

- Year 9 or below
- Year 10/11 or equivalent

Year 12 or equivalent
TAFE / Trade / Certificate / Diploma
Bachelor Degree
Graduate Diploma / Graduate Certificate
Postgraduate Degree
Prefer not to say

Q22. Which ONE of the following best describes your current employment situation?
Working full-time for pay
Working part-time for pay
Self-employed
Working without pay in a family/other business
Unemployed, looking for work
Retired
Full-time student
Household duties not looking for paid work
Not working because of a disability
Other (please specify):

Q23. Have you or any member of your household worked (with or without pay) in any of the industries or sectors?
Marketing, market research, or advertising
Beef / lamb & mutton production or processing
Other types of agriculture
Veterinary medicine
Public sector, policy development, or politics
Non-government, humanitarian, or animal rights organisation
Biotechnology research services
None of these

Q24. How would you characterise your level of political engagement?
Not engaged
Somewhat engaged
Very engaged
Prefer not to say

Q25. Do you or anyone in your family have an inherited genetic disease or condition?
Yes
No
Don’t know/unsure

Q26. Is there anything else that you would like to say about gene editing in beef, lamb & mutton production, or about the research in general?

8.3. Appendix C: Confirmatory focus group design

Day 1

Topic 1/4 Questionnaire

Before we begin the discussion, please tell us a bit more about yourself by filling out this brief questionnaire.

How would you characterise your level of political engagement?

Not engaged
Somewhat engaged
Very engaged
Prefer not to say

Do you consider yourself to be religious? y/n

Do you or anyone in your family have an inherited or genetic disease condition? y/n

On average, how often do you eat beef or sheepmeat (lamb & mutton)?

Don't eat meat at all
Don't eat beef, but eat other meat
Don't eat sheepmeat, but eat other meat
Less than once a week
Between one and three times a week
Between three and five times a week
Almost every day or every day

What are your main reasons not to meat (select all that apply)?

religious reasons
I don't like the taste
Health reasons
Animal welfare concerns
Environmental concerns
Other (please specify):

On a scale of 1–7, where 1 is 'completely disagree' and 7 is 'completely agree', please indicate your level of agreement with the following statements

People have a right to eat meat
Australian livestock farmers deserve better prices and purchase conditions from supermarkets
Livestock animal-welfare standards in Australian abattoirs are very high
Live animal exports from Australia should continue
Compared with overseas, Australian abattoirs operate to good livestock animal welfare standards
The standard of animal welfare on Australian farms needs to be improved
Increased regulation of the treatment of livestock animals is needed.
It is unethical to produce livestock for meat consumption.

On a scale of 0 – 10, how much do you agree or disagree with the following statements about science and technology. Using a scale from zero to 10, where zero means 'strongly disagree', and 10 means 'strongly agree'

Science and technology can solve most problems faced by human beings.
It is important for governments to regulate new technologies.
Scientific advances tend to benefit the rich more than they benefit the poor.
Technological change happens too fast for me to keep up with.
New technologies excite me more than they concern me.

Which of the options below best describe your current awareness of gene editing?

Never heard of
Have heard of, but know little or nothing about
Know enough about it that I could explain it to a friend
Can't say/ don't know

Topic 2/4 Introductions

Welcome to the forum! Let's start off by introducing ourselves. Please share with us a bit about yourself and describe (with words or images) what comes to mind when you see the term 'gene'.

Topic 3/4: Information on gene editing in livestock production

[Participants are randomly assigned to watch one of two video treatments: A: Science / B: Meat]

To help with our discussions over the next couple of days, please watch this brief video about gene editing and answer the following questions.

On a scale of 0–10, where 10 is completely supportive and 0 is completely against it, please indicate how supportive you are of the use of gene editing in Australian beef and sheepmeat production.

On a scale of 0–10, where 10 is completely supportive and 0 is completely against it, please indicate how supportive you are of the use of gene editing in medical applications

Do you think gene editing will generally improve our way of life in the future, OR have no effect, OR make things worse in the future?

Improve our way of life in the future
Have no effect
Make things worse in the future
Don't know/not sure

Topic 3/4:

What comes to mind after watching the video? What else do you think is important for you to know about gene editing before it is used in commercial beef and sheepmeat production in Australia? Please add your own questions and comments. You can also reply, react, or add to other people's posts.

Topic 4/4:

Before we end day 1, please tell us a bit about what you thought of the introductory video.

In your view, was the introductory video:

Completely biased against gene editing
Somewhat biased against of gene editing
Neutral/balanced
Somewhat biased in favour of gene editing
Completely biased in favour of gene editing

What sort of things would make you think a video like this was biased/not biased?

How credible did you find the information in the video?

Completely uncredible
Somewhat uncredible
Neither credible/nor uncredible/don't know
Somewhat credible
Completely credible

What sort of things helped you decide about the credibility?

In your view, what do you think is the primary goal of gene editing for:

Researchers?
To improve animal welfare
To make meat production more sustainable
To increase production output
Other (Please describe):

The Australian beef/sheepmeat industry as a whole?
To improve animal welfare
To make meat production more sustainable
To increase production output
Other (please describe):

Individual beef/sheep producers?
To improve animal welfare
To make meat production more sustainable
To increase production output
Other (please describe):

Is there anything else that you would like to say about the topics discussed today or about the focus group so far?

Day 2: Welcome back! Today we are interested in exploring your views in more detail.

Task 1/2: Q-sort

Please follow the link below, which will take you to our first exercise for the day. There are instructions on the site to guide you through the task. Please remember to return to this page once you have completed the task to continue with today's discussion.

Task 2/2: What is your current view on / feelings about the use of gene editing in beef and sheepmeat production? (please provide as much detail as possible)

Day 3: Specific applications

Welcome back to the final day of our focus group. Today we will be discussing some specific applications of gene editing to address issues in Australian beef and sheepmeat production. None of these applications are currently in use commercially in the Australian beef or sheepmeat industry but are areas of active research.

Please read the following descriptions of how gene editing might be used in the future in Australian beef and sheepmeat production. We would like to hear your impressions of the use of gene editing in each of these scenarios. Feel free to ask us questions if you need more information, although we might not know all the answers.

Topic 1/5: Hornless cattle and sheep

Peter is a commercial beef producer in Queensland. He runs a breeding program to produce high-quality beef cattle, which he sells to feedlots. He uses a breed that typically grows horns. Cattle with horns have a greater risk of causing injuries to workers and other animals, as well as damage to infrastructure. They are also more difficult to handle and require more space during transport and on feedlots. Like most farmers with horned cattle breeds, Peter finds it necessary to remove the horns mechanically.

Not all cattle grow horns; a single, naturally occurring and dominant gene is responsible for this hornless trait. Peter has tried crossbreeding his cattle with a hornless breed, but it is a slow process, which has resulted in reduced productivity and meat quality. If any calves do grow horns, Peter has to remove these while the calves are young. Peter follows best practice guidelines, but still hates removing the horns because he knows that that calves experience considerable pain during and after the procedure. In an effort to eliminate the need to dehorn, he has contacted a research team to ask whether gene editing might offer a solution.

The researchers tell him that it is possible to use gene editing to insert the hornless gene into the genome of a horned breed, resulting in the creation of hornless calves. However, this use of gene editing is still at the research stage and is not used commercially in Australian beef production.

In general, how do you feel about this use of gene editing and the possibility that it might be introduced to Australian meat production in the future? (please provide as much detail as possible about why you feel the way you do)

Topic 2/5: Producing more male offspring

In 2020, a gene edited bull calf named Cosmo was born at a research facility at the University of California, Davis. Using CRISPR, scientists inserted a gene that initiates male development in cattle and sheep. This means that Cosmo has a higher chance of producing male calves because calves that inherit this gene will grow and look like males, regardless of whether they inherit a Y chromosome.

The motivation behind this research is that male beef cattle and meat sheep are more efficient at converting feed into muscle and tend to reach the market at a heavier weight. In other words, this use of gene editing could help increase the amount of meat produced without requiring more animals or environmental or other resources.

In general, how do you feel about this use of gene editing and the possibility that it might be introduced to Australian meat production in the future? (please provide as much detail as possible about why you feel the way you do)

Topic 3/5: Increasing disease resistance in livestock

Joan and Mark run neighbouring sheep farms. They are worried that serious infectious diseases or parasitic infections might spread to their flocks. If that happens, it might reduce animal production or force them to euthanise animals in order to prevent further spread.

Both Joan and Mark have control programs in place, which combine chemical treatments, grazing management, nutritional management, biological control, vaccination and veterinary medicine treatments. Joan is happy with these management practices and is confident that they protect the health of her animals.

However, Mark is worried about the use of chemicals and antibiotics. He is especially concerned that continued use might cause pests and bacteria to become resistant. He has heard that researchers are using gene editing to provide animals with greater resistance to some infectious diseases, thereby potentially reducing the need for antibiotic treatments. He also knows that scientists are looking for ways to edit the genes of pests and parasites to prevent them from transmitting diseases or to prevent them from reproducing normally.

Mark is excited about the possibility that gene editing might help him to protect the health of his flock in the future, but Joan thinks this is tampering too much with nature and is likely to cause unintended consequences.

How do you feel about the ways Mark and Joan are trying to address the problem of livestock health on their farms, including the possible use of gene editing in the future?

Topic 4/5: Consuming gene edited meat

Although Leslie and Alex both like to eat meat, they don't buy it very often. Leslie thinks it is too expensive and Alex is worried that eating more meat could contribute to heart disease and poor health in the future.

One day, they see a news story about gene editing research that could make meat both more affordable and healthier. Scientists have found a way to create animals that are more efficient at turning feed into muscle by inactivating a gene that regulates muscle growth, leading to so-called 'double muscling.' The researchers are hopeful that this will allow more meat to be produced without increasing production costs. Meat produced by double muscled animals also tends to be leaner and might therefore be more heart friendly. Both Leslie and Alex are excited that they might be able to eat more meat in the future because of gene editing.

Do you think Leslie and Alex are right to be excited about this possible use of gene editing? Why/why not?

Topic 5/5: Discussing gene editing

Has anything you discussed during the course of this forum (either within the group or with others) changed how you think about gene editing? If so what?

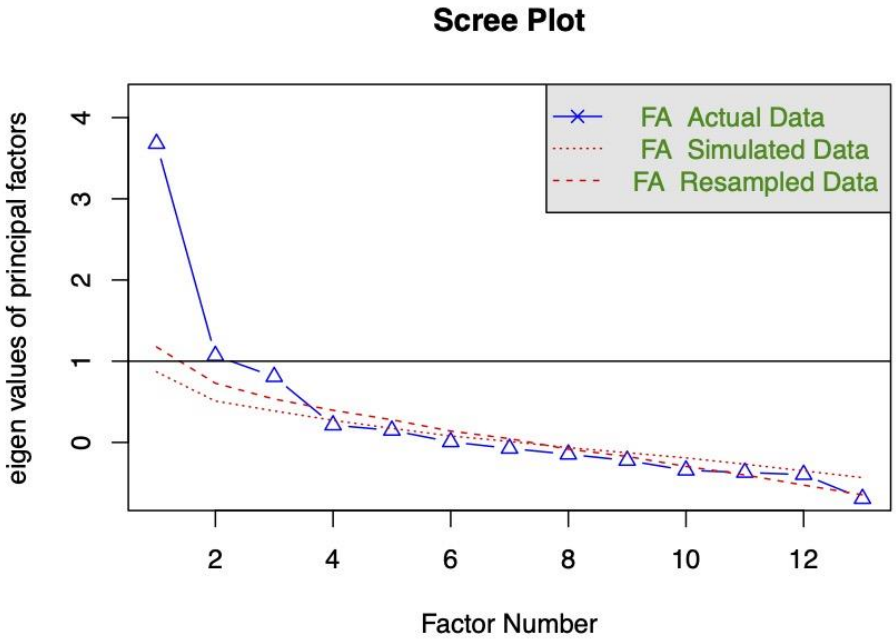
We have asked all our questions, but is there anything else that you would like to say about the topic?

8.4. Appendix D: Analysis of video treatment

To explore the effect of the video treatments on these post-video responses, we conducted a categorical regression that included the respondents' views on Australian livestock production and on science and technology as pre-video responses and the video treatment as explanatory variables. The pre-video responses were included to account for any pre-existing attitudes that could be factored out of the model to concentrate on the video treatment effect.

Before running each model, we first performed a factor analysis combining all of the pre-video questions to determine a smaller set of potentially confounding variables. The first three factors were found to explain more variation than expected, and were added as covariates to model (see Figure 46). Accordingly, for each question, the final model comprised the three factors, capturing the pre-video responses, and the video treatment as the fourth explanatory variable. After running the model, we predicted the proportion of individuals falling into each of the post-video categories, then averaged these proportions across all factors to get the expected value specific to each video treatment. Finally, we compared the proportion of respondents in each response category between the Science and Farmer treatments, to investigate if there was a systematic difference in the impact of the video treatment on the post-video responses.

Figure 39: Scree plot showing the Eigenvalues for the extracted factors compared to expected values for simulated and resampled data. The first three factors have eigenvalues greater than expected, and were therefore selected for inclusion in the model.



8.5. Appendix E: Sample characteristics

8.5.1. Preliminary focus group sample:

Figure 40: Number of preliminary focus group participants from each Australian state and territories (n=60)

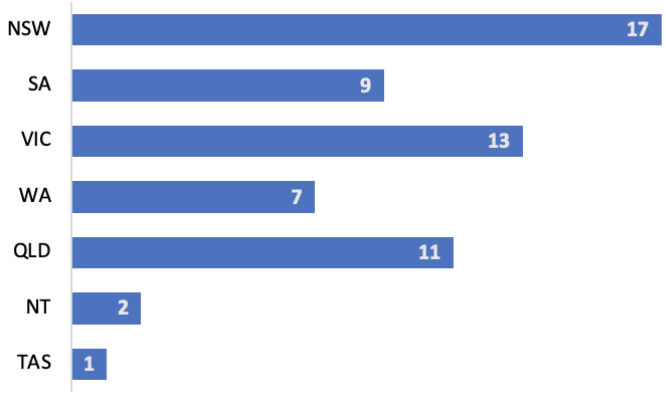


Figure 41: Number of preliminary focus group participants who live in rural and non-rural areas (self-reported, n=60)

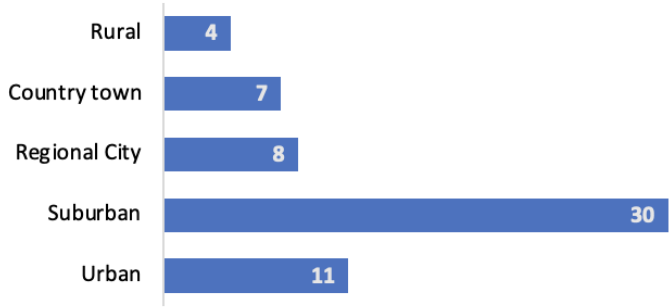
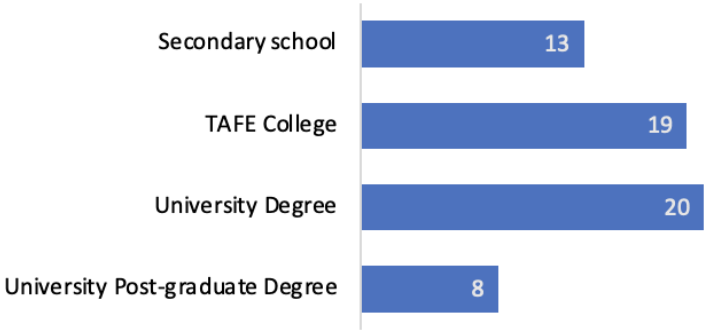


Figure 42: Highest completed education level of preliminary focus group participants (counts, n=60)



8.5.2. Confirmatory focus group sample

Figure 43: Number of confirmatory focus group participants from each Australian state and territory (n=62)

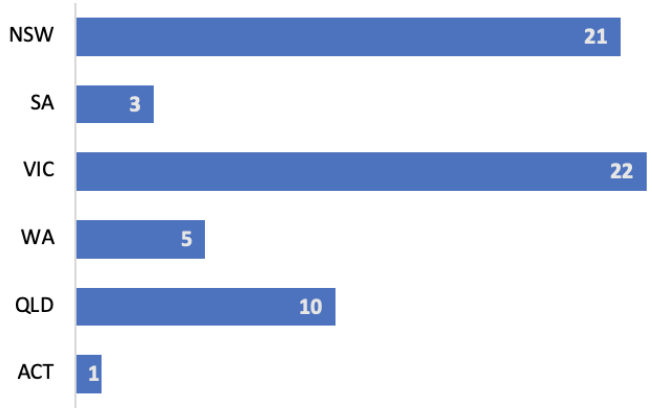


Figure 44: Number of confirmatory focus group participants who live in rural and non-rural areas (self-reported, n=62)

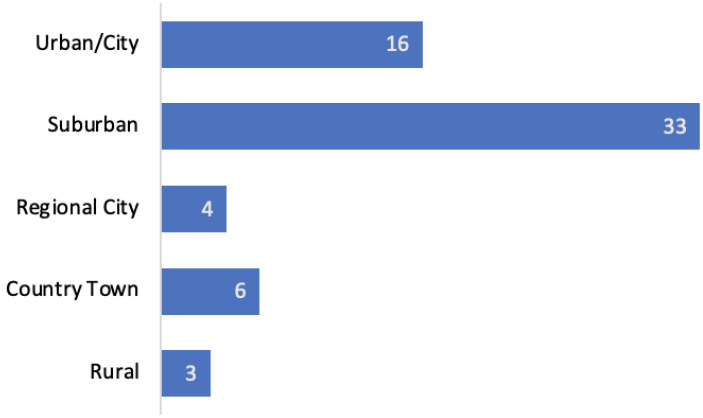
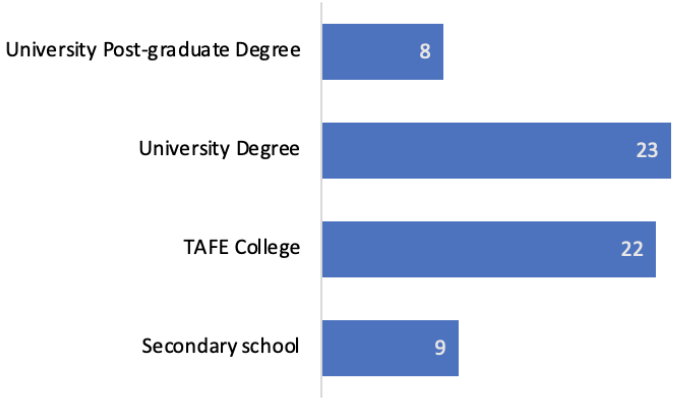


Figure 45: Highest completed education level of preliminary focus group participants (counts, n=62)



8.5.3. Video treatment sample

Table 6. Percentage of participant types in the 'farmer' and 'scientist' video treatments.

		Treatment group	
		'farmer'	'scientist'
Gender	Female	25%	25%
	Male	24%	27%
Age range	18–24	4%	11%
	25–29	8%	11%
	30–34	8%	17%
	35–39	8%	15%
	40–44	8%	9%
	45–49	10%	8%
	50–54	10%	8%
	55–59	12%	11%
	60–64	14%	4%
	65+	16%	6%
Education	Secondary school	11%	7%
	TAFE College	16%	25%
	University Degree	17%	13%
	University Post-graduate Degree	5%	8%
Diet	Flexitarian	12%	9%
	Lacto-vegetarian	2%	6%
	Omnivore	73%	79%
	Ovo-vegetarian	0%	2%
	Pescatarian	4%	0%
	Vegan	6%	4%
	Lacto-ovo-vegetarian	2%	0%

8.6. Appendix F: Q-factor analysis

8.6.1. Factor loading (z-score) for each statement by extracted factor

Table 7: Factor loadings (z-score) for each of the statements for each of the extracted factors

Statement Number	Factor 1 Z-score	Factor 2 Z-score	Factor 3 Z-score	Factor 4 Z-score	Factor 5 Z-score
1	-0.95183	0.82936	-1.25403	-0.0811	-0.96931
2	-0.12493	1.08855	-1.01529	-0.02531	-1.16716
3	0.8431	-0.96159	1.06658	-0.03171	0.67304
4	0.29418	1.03471	-0.41898	0.31857	0.76752
5	-1.54408	-0.44969	-0.18115	0.96959	-0.09948
6	0.25605	-1.94043	-0.69609	-0.90165	0.05616
7	-0.30693	1.14628	1.06807	0.84505	-1.25948
8	-0.94421	1.00242	-2.29449	0.7879	-0.54464
9	-1.60485	-0.00397	-1.65634	-1.5677	1.31998
10	-0.85332	0.27773	-0.84155	0.76328	-0.70916
11	0.19871	0.30976	-0.0173	-0.4683	-0.21507
12	1.08937	-0.75708	0.02623	0.90623	-0.68809
13	0.93018	-1.5044	-1.50605	-0.30028	-0.17789
14	1.57934	-0.36257	0.91937	-1.67508	0.14779
15	1.12377	-1.71961	-0.3925	0.90327	0.89596
16	-0.56195	0.18376	0.01337	-0.91645	1.52789
17	1.74189	0.26101	1.15906	0.73204	-0.59144
18	-0.84367	-0.32138	-0.36054	-1.88304	0.68809
19	0.86251	-1.07466	0.16248	0.18526	0.04831
20	1.0523	-0.69202	0.39797	0.80031	-0.64191
21	0.17835	0.94447	1.56795	-1.45012	-1.47169

Statement Number	Factor 1 Z-score	Factor 2 Z-score	Factor 3 Z-score	Factor 4 Z-score	Factor 5 Z-score
22	-0.04965	0.27221	0.20409	0.74902	-1.62737
23	1.31551	-0.66743	-0.75784	0.83955	-0.458
24	-2.19287	-1.50369	0.98006	1.02576	1.86028
25	0.96877	0.30954	-0.67863	-0.14235	-1.7068
26	1.14234	1.27208	1.42716	0.42272	1.1744
27	-1.04341	1.29035	-0.71368	-0.19844	-0.14063
28	0.88775	-1.40936	-1.67246	-0.08397	0.27839
29	0.88187	-1.75526	0.35573	-0.81449	-1.96696
30	-0.57793	1.63118	-0.37793	1.99813	1.14998
31	-0.44927	1.16431	1.37496	-0.87637	-0.2179
32	0.70508	1.2325	1.58094	-0.63129	-1.25776
33	1.31335	-0.53044	0.45004	0.09669	0.37288
34	0.91471	1.45669	0.44592	1.00066	0.21618
35	-1.23606	0.08686	1.36485	-1.59987	-0.32957
36	-0.61244	-0.09108	-0.63354	-1.05346	0.70094
37	-0.91473	0.08766	-0.10713	1.83645	1.48674
38	-1.17862	0.22492	0.42782	-0.81981	0.14566
39	-0.73845	1.01413	0.00233	-1.63402	1.98303
40	-0.61876	0.01868	1.13074	1.54728	-0.75251
41	-0.1311	-1.32006	0.94846	0.36251	1.08993
42	-0.80005	-0.07442	-1.49864	0.06457	0.40966

8.6.2. Interpretation of Discourse 1-

This section provides an interpretation of the perspective of participants who are negatively associated with Discourse 1.

Forty-three Q-sort respondents are significantly associated with Factor 1, of which 19 participants are also associated with one other factor. Seven participants are negatively associated with Factor 1, which indicates that two opposing views are expressed by participants who are associated with this discourse. The positively associated perspectives are interpreted in Section X, while the negatively associated perspectives (Discourse 1-) are interpreted below:

Discourse 1- : Unethical and unnecessary

Discourse 1 is bipolar, meaning that some participants are negatively associated with the discourse. A Q-sort completed by a negatively associated participant will be a 'mirror-image' of positively associated participant. This suggests that a similar reasoning underlies their Q-sorts, but they are nevertheless coming to opposite conclusions.

Participants who are negatively associated with Discourse 1 view gene editing in livestock production as unnecessary, unethical, and dangerous, as illustrated by the following quote by this female focus group participant from Sydney:

> *My current views and feelings about the use of gene editing in beef and sheep meat production is that it is disgusting and inhumane and shouldn't be happening as it could have dangerous effects on the animals and humans in the long run… Animals should be able to live their life not be genetically changed [and] shouldn't be treated as lab rats.*

8.6.3. Participant factor loadings (z-scores) by factor

Table 8: Rotated factor loadings (z-score) for each participant. Factor loadings indicate the extent to which each participant's Q-sort exemplifies each factor (discourse). Loadings that are significant at the 0.01 level 0. (z-score $\geq$ 0.398) are bolded. Factor defining Q-sorts are followed by an asterisk (*). Majority of common variance is required, which means that each Q-sort contributes to the definition of only one factor.

Participant Number	Factor 1		Factor 2		Factor 3	Factor 4		Factor 5
1	0.03863		**0.7486**	*	-0.07857	0.05062		0.16933
2	**0.53726**	*	-0.09735		0.22923	-0.13139		-0.16867
3	**0.82063**	*	-0.28907		0.05246	0.07254		0.00959
4	0.32783		**0.76626**	*	-0.05164	-0.12862		-0.04029
5	0.20757		0.06358		0.28613	**0.48245**	*	-0.27018
6	-0.22046		0.21272		**0.46374**	0.23848		0.25954
7	**0.5516**		0.10778		0.07844	0.2377		**0.56127**
8	-0.14161		**0.75007**	*	-0.04408	-0.17578		0.06615
9	**0.597**	*	-0.27729		0.12511	-0.26169		-0.09915
10	-0.14459		0.01475		0.12228	-0.32309	*	0.01588
11	**0.53621**		**0.60066**	*	-0.07161	-0.08989		-0.05019
12	-0.15528		-0.07662		-0.03699	0.01649		-0.11152
13	0.19311		**0.59825**	*	0.15477	-0.01544		-0.01712
14	**0.68961**	*	-0.0263		0.03912	0.09784		-0.21157
15	-0.17793		0.35761		-0.38109	0.15197		-0.08009
16	0.13282		0.31615		-0.04623	-0.13723		0.36427
17	-0.26266		-0.1308		0.05371	0.21951		-0.09173
18	0.16524		**0.40215**	*	0.05261	-0.14558		-0.1964
19	**0.48452**	*	0.20358		0.21687	0.05037		0.32192
20	**0.74066**	*	-0.25526		-0.0062	0.33956		-0.13267
21	-0.252		0.34794		0.25844	**-0.43809**		0.14167
22	**0.45808**	*	-0.24567		0.04708	0.09373		-0.06279
23	**0.5747**	*	-0.15426		0.07223	0.12596		-0.04683
24	**0.69818**	*	-0.02422		-0.16558	-0.06207		-0.14315

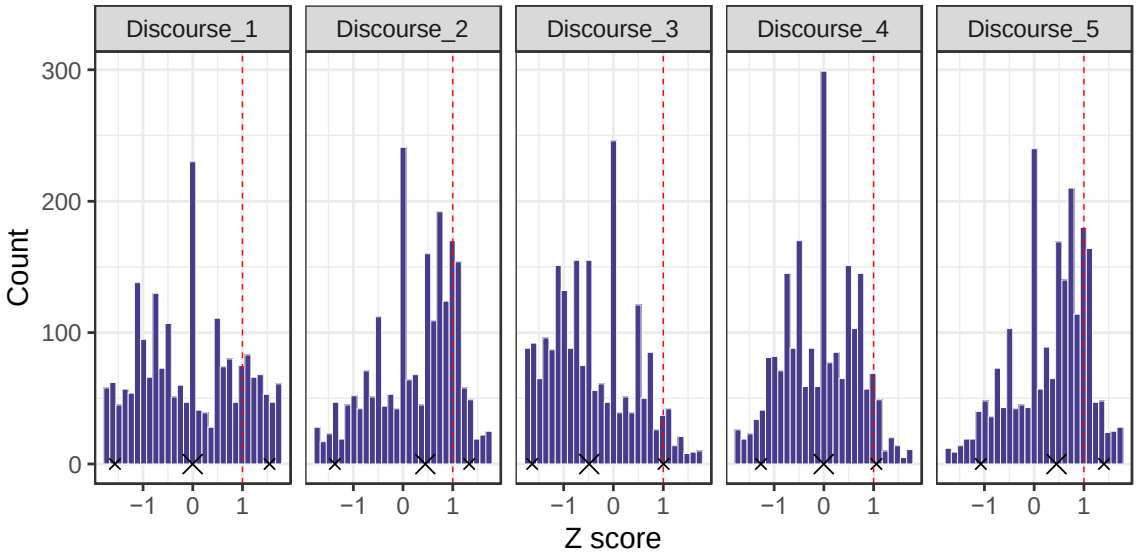
25	0.06349		0.10088		**0.74262**	*	0.00197		-0.13209	
26	**0.7392**	*	**-0.39403**		0.10633		-0.06097		-0.04837	
27	-0.27677		0.16989		**0.54457**	*	-0.15693		-0.19129	
28	0.35205		-0.09381		0.34143		-0.23818		-0.17898	
29	0.03396		**0.54279**	*	-0.20437		0.35617		-0.00974	
30	**0.68105**	*	-0.193		-0.12236		-0.11436		0.03267	
31	0.00717		-0.15081		0.17822		**-0.38973**		0.32524	
32	**0.53401**	*	0.27473		0.05058		-0.10093		0.28151	
33	**-0.51337**		**0.49086**		0.04759		-0.16003		-0.26193	
34	**0.77228**	*	0.08261		-0.02545		0.14113		-0.06949	
35	**0.71565**	*	-0.21093		0.18738		-0.01108		-0.14501	
36	-0.07381		0.33107		0.27897		**0.42199**		0.10961	
37	**0.71909**	*	0.21778		-0.05858		0.04232		0.09816	
38	0.36651		0.32995		0.26032		0.07131		**-0.5784**	*
39	**0.79251**	*	-0.10197		-0.01057		-0.03332		0.08663	
40	-0.022		**0.74616**	*	0.04071		0.2134		-0.03974	
41	0.38245		**0.44166**		0.10468		0.17949		0.22091	
42	**-0.62618**	*	**0.4266**		-0.19257		-0.00074		-0.18513	
43	0.05622		**0.756**	*	0.20043		-0.07704		0.00648	
44	**0.77257**	*	-0.08125		-0.07872		0.07451		0.16827	
45	0.12896		0.08251		-0.13663		-0.34791	*	0.0269	
46	0.04571		-0.09268		**0.4362**	*	-0.03		0.0456	
47	0.08902		**0.41151**		0.27565		0.09004		0.32958	
48	0.24971		**0.45931**		0.18688		0.35724		-0.12894	
49	**-0.54212**	*	**0.50861**		0.07595		-0.07482		-0.01461	
50	0.10998		**0.78708**	*	-0.17112		0.06489		0.01222	
51	0.04124		**0.61853**	*	0.37413		0.09909		0.0746	
52	**0.50019**		0.01311		-0.06121		0.01639		**-0.51099**	*
53	**0.66714**	*	0.03061		0.32635		0.06052		-0.20008	
54	0.29514		**0.6843**	*	0.09536		-0.01836		-0.03078	
55	**0.66872**	*	0.24491		0.18187		-0.07336		0.1379	

56	**0.57779**	*	0.0146		0.07804		-0.32011		-0.10881	
57	-0.24811		**0.79622**	*	-0.23699		-0.02587		-0.09677	
58	0.29771		**0.5012**		0.07366		0.10723		**0.4977**	
59	0.05421		-0.14719		0.05446		-0.10885		**0.65139**	*
60	0.16168		-0.00828		**0.66217**	*	-0.12603		0.32522	
61	**0.78994**	*	-0.00604		-0.05129		-0.13121		0.13184	
62	-0.10242		0.00573		0.01416		0.25237		**0.48881**	*
63	-0.2004		**0.57331**	*	-0.11534		0.15975		-0.02315	
64	**0.43854**	*	0.03666		-0.05938		0.1587		-0.24051	
65	-0.10466		**0.42813**		**0.54967**	*	0.15343		0.09552	
66	**-0.41496**		**0.68288**	*	-0.03383		-0.04823		-0.10726	
67	**0.55793**	*	0.27916		-0.17324		-0.09836		-0.32025	
68	**0.39081**		-0.03882		**0.53521**	*	-0.05582		0.01914	
69	**0.76985**	*	-0.0165		0.00721		0.05916		-0.09938	
70	**0.65393**	*	-0.29578		0.19419		-0.00316		0.24742	
71	0.36601	*	0.18512		-0.17203		0.07199		-0.20062	
72	-0.38254		**0.71247**	*	0.12623		0.10606		-0.07606	
73	**-0.5615**	*	**0.44388**		-0.13364		-0.13447		0.00464	
74	**0.69993**	*	-0.15941		0.00192		-0.08178		0.13492	
75	**0.57983**	*	-0.08302		0.1794		-0.34753		-0.1873	
76	**0.54881**	*	0.29569		0.30058		0.16869		-0.00763	
77	**0.53094**	*	-0.31852		0.00084		-0.2079		-0.21482	
78	0.32179		**0.60801**	*	0.36113		0.03979		-0.01632	
79	**0.67671**	*	-0.24061		-0.1043		0.02614		-0.12019	
80	-0.28714		**0.47242**	*	0.10702		-0.2947		0.03861	
81	**0.44058**		0.07032		0.05254		**-0.42573**		**0.42163**	
82	-0.24458		0.05988		-0.14213		**0.56342**	*	-0.08961	
83	**0.70545**	*	-0.11337		0.16185		-0.25567		-0.03628	
84	-0.36882		-0.0822		0.36806		-0.11904		-0.05289	
85	-0.24314		**0.44257**		**0.42537**		0.01956		**0.53514**	
86	**0.71836**	*	**0.43948**		0.0281		-0.07219		-0.0448	

87	-0.32147	**0.52626**	*	0.27343		0.01062		0.16954	
88	0.31553	0.31269		0.13918		-0.2171		0.16	
89	-0.03788	**0.69381**	*	-0.01956		0.07689		-0.17356	
90	0.05144	0.089		0.05443		**0.67386**	*	0.1449	
91	-0.264	**0.75107**	*	-0.15157		-0.06597		0.11097	
92	-0.36703	**0.53682**	*	0.18638		-0.19804		0.02595	
93	**-0.41178**	**0.61297**	*	-0.03409		-0.17164		0.29291	
94	-0.32745	**0.6373**	*	-0.183		-0.10893		0.04653	
95	0.29145	**0.4403**		0.33723		0.19986		0.10381	
96	-0.20779	**0.66831**	*	0.32975		0.10606		0.09836	
97	**0.47253**	0.06136		**0.61809**	*	-0.06946		0.24294	
98	-0.134	0.11512		0.14757		**-0.5549**	*	0.12665	

8.7. Appendix G: Distribution of z-scores estimating survey participants' association with the identified discourses

Figure 46: Distribution of z-scores for each discourse. Z-scores indicate respondents' association with each discourse. Large X marks the median z-score for each discourse, while small x marks the upper and lower 5% boundaries. The red dashed line marks the cut-off point for respondents who are associated with each factor (z-score=1). Respondents who are associated with multiple or no factors are omitted.



8.8. Appendix H: Correlation between attitudes toward livestock production and the acceptability of gene editing applications

Table 9: The effect attitudes toward the Australian livestock industry on the acceptability of gene editing applications in beef and sheepmeat production. The acceptability of the Australian livestock industry is assessed based on respondents' rating of their agreement with a set of statements (rows) on a 7-point Likert-type scale, where 1=completely disagree and 7=completely agree. The statements for both variables have been abbreviated. Level of acceptance for gene editing applications in beef and sheepmeat production (columns) are measured on a 5-point Likert-type scale, where 1=completely disagree and 5=completely agree.

** p < 0.10, ** p < 0.05, *** p < 0.01*

	How ethically acceptable or unacceptable do you feel it is to use gene editing to…											
	enhance muscle mass	enhance the eating quality of meat	make meat healthier	make more disease resistant	reduce the need for painful procedure	reduce environmental impact	alter coat colour and thickness	alter the temperament	reduce reproductive ability of pests	adapt livestock to new environments	increase the birth rate of male animals	enhance the ability of livestock to digest lower quality feed
People have a right to eat meat	0.05**	0.07***	0.07***	0.06**	0.05*	0.04*	0.03	0.06***	0.09***	0.05**	0.07***	0.01
	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02
Producers deserve better purchase conditions	0.02	0.05**	0.04*	0.08***	0.06***	0.03	0.05**	0.07***	0.07***	0.05**	0.01	0.03
	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02
Long-distance transport should continue	0.15***	0.12***	0.06***	0.02	-0.01	0.03	0.09***	0.10***	0.03*	0.07***	0.13***	0.15***
	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02
The standard of animal welfare needs to be improved	-0.01	-0.03	-0.02	-0.02	-0.01	0	-0.04*	-0.03	-0.02	-0.02	-0.04	0
	-0.02	-0.03	-0.02	-0.02	-0.02	-0.02	-0.02	-0.03	-0.02	-0.02	-0.02	-0.03
Increased regulation of meat	-0.02	0.02	0.01	0.01	0.03	0	0.02	0	0.01	0	0.01	-0.05**

production is needed												
	-0.02	-0.02	-0.03	-0.02	-0.02	-0.02	-0.02	-0.03	-0.02	-0.02	-0.02	-0.03
The welfare of livestock on feedlots is lower than that free-range	-0.06***	-0.06**	-0.05**	-0.01	-0.02	-0.01	-0.03	-0.07***	-0.01	-0.04*	-0.06***	-0.09***
	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02
It is wrong to raise cattle and sheep for meat production	0	-0.04*	-0.05**	-0.06***	-0.03*	-0.02	0	0.03*	-0.06***	-0.01	0.03*	0.07***
	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02