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Consumer Responses to the Use of NBTs in the Production of Food: A Systematic Literature Review

The Australian National University

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Contents

1. Executive summary

This document responds to Food Standards Australia New Zealand's RFQ 2020-21/19, 'Literature review on consumers' response to the use of new breeding techniques (NBTs) in the production of food'.

In this review we summarise and assess the available evidence in the scholarly and relevant grey literature about the awareness and knowledge, risk perceptions, and behavioural responses of consumers to the use of new breeding techniques in the production of food. To do this we have conducted a systematic search for relevant peer-reviewed and grey literature, finding 146 studies of varying relevance to the question at hand. One hundred and eleven of these were empirical or offered new data; 35 were either discussion, synthesis, opinion, or other.

Key findings of the review are that:

- The literature in this space is limited, and riven with gaps and methodological, framing, and other biases. In particular, much work has covered consumer acceptance, but less has explored the underlying values, policy considerations, and contexts within which people consider and assess NBTs used in the production of food.
- The literature that does exist currently suggests attitudes and behavioural responses to NBTs are slightly more positive than toward older forms of genetic modification (GM), and slightly more negative than toward food produced using traditional breeding techniques.
- This relatively more positive attitude could be due to the 'more targeted' and 'less distant' nature of NBTs compared with more 'random' and 'distant' GM techniques; it could also be a result of the framing biases of the research thus far conducted.
- With this in mind, it is apparent that there are significant risks in this space relating to promotion of public understanding, engagement, and communication, and key stakeholders need to consider carefully how to proceed.
- Many key aspects of NBTs (such as their potential benefits for animal welfare and their lack of traceability) represent tricky loci for engagement and communication, where the path forward is not simple.
- Better practices for engagement and communication require more rigorous research that explores the intersection of values and responses to NBTs, including what people want to know, who or what they have confidence in as sources of information, and in what ways they wish to obtain information or be engaged about NBTs in food production.
- Given the potential for highly fractious debate, spaces and mechanisms that permit deep community engagement and deliberation about food production processes need to be fostered.

2. Introduction

The emergence of New Breeding Techniques (NBTs) over the last decade has presented food regulators around the world with an interesting challenge. Where older technologies of genetic modification (GM) had offered promise – but sparked widely ranging consumer receptions – NBTs offer food producers a variety of means to achieve increased producer, consumer, or environmental benefits, while achieving potentially more positive receptions than food produced using older GM techniques. As Bartkowski and Baum noted in 2019,

> The new possibilities offered by genome editing, particularly via novel methods like CRISPR-based systems … entail that existing governance solutions for genetically modified (GM) food are rendered (at least partly) obsolete. It thus becomes unclear how applications of genome editing in the food sector should be governed and regulated, or whether any special regulation is in fact necessary at all.

A variety of authors and scientific institutions have either called for (Araki and Ishii 2015), noted the need for (Bartkowski et al. 2018), discussed (Nature 2021), or applauded (Barrangou 2020) new regulations around the world associated with NBTs used in the production of food.

As noted in the call underpinning this Literature Review, Food Standards Australia New Zealand (FSANZ) is undertaking work

> to amend the definition *of food produced using gene technology* in the Australia New Zealand Food Standards Code. This definition determines what foods are subject to pre-market assessment and approval as genetically modified (GM) foods. The purpose of revising the definition is to modernise the regulatory approach to GM foods to better reflect both existing and emerging genetic technologies, including new breeding techniques (NBTs) such as genome editing.

The present Literature Review seeks to support FSANZ's work in this endeavour, providing a systematic literature review of what is known about consumers' awareness, knowledge, risk perceptions, and behaviours with regard to the use of NBTs in the production of food.

2.1 New Breeding Techniques

New Breeding Techniques or NBTs are a collection of methods developed in recent years which allow food producers to make targeted changes to a plant or animal's DNA in order to introduce or modify traits of a target species (see FSANZ 2020). Widely used and discussed NBTs include:

- CRISPR-Cas9, Zinc Finger Nucleases, or TALENs, which allow genome editing to modify DNA at one or more specific sites;
- oligonucleotide-directed mutagenesis (ODM) to introduce targeted changes to a small number of bases of DNA;
- cisgenesis (transferring a gene from the same or a closely related species);
- intragenesis (inserting a reorganised regulatory coding region of a gene from the same species); and
- using epigenetic processes to change the activity of genes without changing a DNA sequence.

2.2 Review structure

This systematic review is composed of three key components as follows:

Section 3 presents our method for systematising the review, drawing on the methodological guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA, Moher et al. 2009) and the Manual for Evidence Synthesis produced by the Joanna Briggs Institute (Aromataris 2020).

Section 4 presents our narrative synthesis of what is known from the research collected, organised into sections on consumer awareness and knowledge, risk perceptions, behavioural responses, and arguments from the literature on plausible paths to successful consumer engagement.

Section 5 presents an annotated bibliography of the collected resources.

2.3 Key findings

Key findings of the review are:

2.3.1 The existing literature in this space is limited, and doesn't provide relevant details on key issues

Our first key finding is that the relevant literature in this space is highly limited, and the literature that does exist is riven with gaps and methodological, framing, and other biases.

For instance, there is a preponderance of work on consumers' willingness-to-pay (WTP) for food produced using NBTs (see section 4.4 below). While this work is certainly of value, it does suggest that questions so far asked about NBTs for food production are primarily about consumer WTP as a proxy for acceptance (see 4.4.4), and less about underlying values, policy considerations, or the broader context within which people come to understand technologies such as NBTs. Although WTP can be an important metric for certain kinds of considerations, it is not directly aligned with FSANZ's main interests in consumer attitudes toward NBTs.

2.3.2 Responses appear more positive than toward GM

Secondly, while there are certainly gaps in what is known, the literature that does exist currently suggests that attitudes (see section 4.3) and behavioural responses (see section 4.4) to NBTs are slightly more positive than toward older forms of GM, and slightly more negative than food produced using traditional breeding techniques. It appears (though again, the data here rests on a small number of studies) that perhaps the 'more targeted' and 'less distant' nature of NBTs compared with more 'random' and 'distant' GM techniques is considered positively. However, on this point it should be stressed that more evidence is required: it could be the case that this relative positivity toward NBTs appears as a result of the framing biases of the research thus far conducted (see section 4.3.4).

2.3.3 Communication matters

Thirdly, given the relative paucity of data, methodological biases in the literature (see section 4.2.6 on information provision), and relatively low existing awareness of NBTs (see section 4.2), ongoing discussions and communication about food produced using NBTs will significantly shape attitudes in the future. There are three key implications from this point, as can be seen in the literature discussed below.

One is that while some research has suggested consumers appreciate the potentially 'targeted' nature of NBTs, other researchers have suggested that some of the key aspects of NBTs (such as their potential benefits for animal welfare and their lack of traceability) may present communication challenges (see section 4.3.3).

In addition, better practices for engagement and communication on this issue require more rigorous research that explores the intersection of values and responses to NBTs, including what people want to know, who or what they have confidence in as sources of information, and in what ways they wish to obtain information or be engaged about NBTs in food production.

Finally, it is apparent in the literature discussed below that it is essential, given the potential for highly fractious debate, that spaces and mechanisms that permit deep community engagement and deliberation about food production processes be fostered.

3. Method

In this review we have sought to answer three related questions: What is consumer awareness and knowledge of NBTs? What is the perception of risk about the use of NBTs? How do people behaviourally respond to the use of NBTs?

To answer these questions, we have conducted a systematic search for relevant scholarly and grey literature. Below we outline our process of building from an initial review scope to a working database search string, through reviewing for inclusion, and final data extraction and analysis.

At this point it should be noted that throughout our scoping, searching, and processing stages we worked with a goal of 'generous' or 'wide net' inclusion, that is, treating a false negative (a relevant paper not being included at any stage of search or filtering) as more problematic than high numbers of false positives (papers included in search or filtering stages, but subsequently judged to be irrelevant). To give a simple example of how this process worked, if our reading of a title or abstract suggested only a slight chance of relevance to the final review, we would nevertheless progress that paper to the next stage for deeper reading. Our goal throughout the review process was to ensure confidence in capturing all of the relevant literature.

3.1 Scoping and seed papers

The scope for this review is drawn from the initial definition, to "produce a literature review on consumers' awareness, knowledge, risk perceptions and behaviours of the use of NBTs, including genome editing, in the production of food."

To turn this into a database search string able to capture all of the relevant literature, we first segmented this initial definition into four component areas: the study target (e.g., plants, animals), human factors (e.g., attitudes, understanding), the type of technology (e.g., CRISPR, GM), and location (Australia/New Zealand, elsewhere). Each of these component areas were then expanded into a large list of relevant synonyms, drawing on the experience of the review team, insights from the client, and the keywords identified in several key seed papers covering various aspects of the literature known to already be relevant to the review:

- Bray, H. J., and Ankeny, R. A. (2017). Not Just About "the Science": Science Education and Attitudes to Genetically Modified Foods Among Women in Australia. *New Genetics and Society*, *36*(1), 1-21.
- Critchley, C., Nicol, D., Bruce, G., Walshe, J., Treleaven, T., and Tuch, B. (2019). Predicting Public Attitudes Toward Gene Editing of Germlines: The Impact of Moral and Hereditary Concern in Human and Animal Applications. *Frontiers in Genetics*, 9(704), 1-14.
- Gatica-Arias, A., Valdez-Melara, M., Arrieta-Espinoza, G., Albertazzi-Castro, F. J., and Madrigal-Pana, J. (2019). Consumer Attitudes Toward Food Crops Developed by CRISPR/Cas9 in Costa Rica. *Plant Cell Tissue and Organ Culture*, *139*(2), 417-427
- Marette, S., Disdier, A. C., and Beghin, J. C. (2021). A Comparison of EU and US Consumers' Willingness to Pay for Gene-edited Food: Evidence from Apples. *Appetite*, *159*, 1-11
- Shew, A. M., Nalley, L. L., Snell, H. A., Nayga, R. M., and Dixon, B. L. (2018). CRISPR Versus GMOs: Public Acceptance and Valuation. *Global Food Security-Agriculture Policy Economics and Environment*, *19*, 71-80.

Hence the area of human factors, for example, was expanded to include papers using a range of other keywords including opinion, worldview, WTP, WTC, perception, understanding, trust, and safety.

Each of the four component areas was then segmented into four rings of relevance, radiating outward from our core or essential inner ring, through our second ring of terms (and hence records) likely to be of relevance, to a third ring of possible relevance, and finally to those records that would be deemed out of scope. Figure 1 offers a visual representation of this strategy.

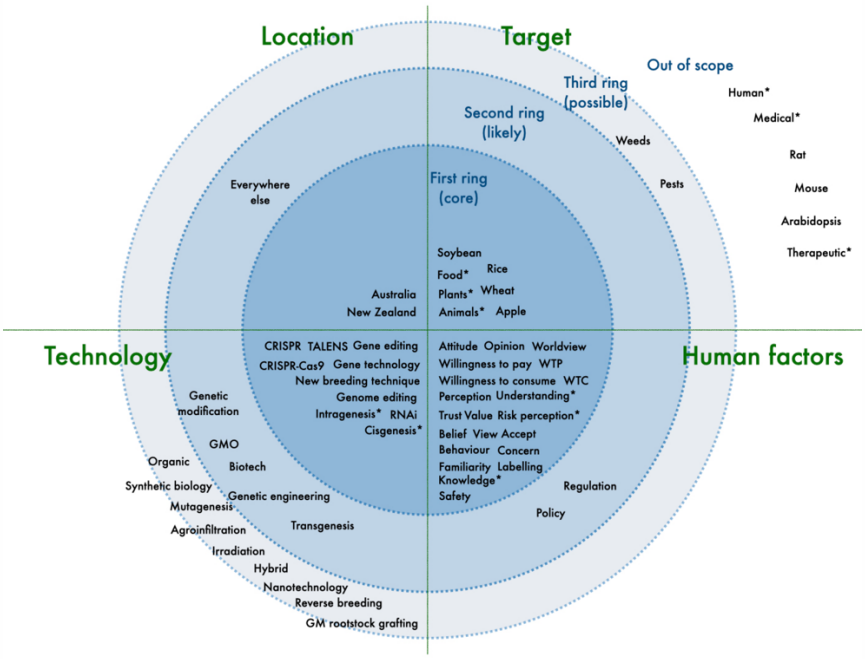

Figure 1 Keywords in component areas

Using these processes, we considered six different categories of literature:

- CORE literature (on human attitudes to NBTs in food, in Australia or New Zealand)
- +WORLD (on human attitudes to NBTs in food, anywhere);
- +REG (on the regulation of NBTs in food in Australia or New Zealand);
- +REG+WORLD (on the regulation of NBTs in food anywhere);
- +GM (on attitudes to other genetic technologies broadly during the GM era but not necessarily GM in food in Australia or New Zealand; and
- grey literature (as per CORE, +GM, and +REG categories, but sourced from the grey literature).

Figure 2 provides a visualisation of this categorisation:

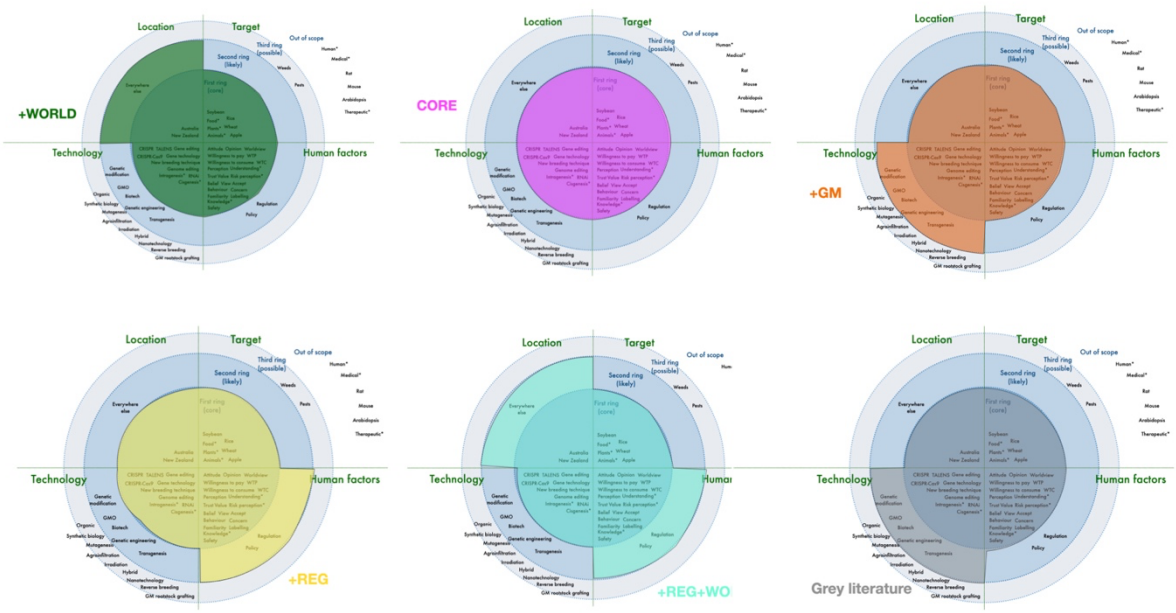

Figure 2 A visual representation of our segmentation of the literature

3.2 Searching

Expert advice on search string development and database dynamics was solicited from a research librarian experienced in conducting systematic reviews with the Joanna Briggs Institute. Following this consultation, we commenced an iterative process of search string development, testing for inclusion of the seed papers and relevance of the produced results. Two strings were developed, focusing on the +WORLD (which included the CORE papers) and the +GM categories. These were tested in a variety of databases (Scopus, Web of Science, and Ovid), and finally run in Scopus and Web of Science as below. (Ovid is an aggregator of other search databases, and was found to provide results that were a subset of those in Scopus and Web of Science). This identified 1130 potential records.

3.2.1 Scopus search strings

TITLE-ABS-KEY ("gen edit*" OR "gen* techn*" OR "new breeding tech*" OR "TALENS" OR "CRISPR" OR "RNAi") AND TITLE-ABS-KEY ("perception*" OR "belief*" OR "attitude*" OR "opinion*" OR "worldview" OR "willingness to pay" OR "WTP" OR "willingness to consume" OR "WTC" OR "accept*" OR "familiarity" OR "trust*" OR "label*") AND TITLE-ABS-KEY ("food*") AND NOT TITLE-ABS-KEY ("mouse" OR "rat" OR "arabidopsis" OR "mosquito") AND PUBYEAR > 1990*

(TITLE-ABS-KEY ("genetically modified organism" OR "GMO" OR "gene modifi*" OR "gene* engineer*" OR "biotech*") AND TITLE-ABS-KEY ("perception*" OR "belief*" OR "attitude*" OR "opinion*" OR "worldview" OR "willingness to pay" OR "WTP" OR "willingness to consume" OR "WTC" OR "accept*" OR "familiarity" OR "trust*" OR "label*") AND TITLE-ABS-KEY ("food*") AND TITLE-ABS-KEY ("Australia*" OR "Queensland" OR "New South Wales" OR "Victoria*" OR "Tasmania*" OR "Australian Capital Territory" OR "Northern Territory" OR "South Australia*" OR "Western Australia*" OR "New Zealand") AND NOT TITLE-ABS-KEY ("mouse" OR "rat" OR "arabidopsis" OR "mosquito") AND PUBYEAR > 1990)*

3.2.2 Web of Science search strings

TS=("new breeding tech" OR "gen* edit*" OR "gen* tech*" OR "TALENS" OR "CRISPR" OR "RNAi") AND TS=("perception*" OR "belief*" OR "attitude*" OR "opinion*" OR "view*" OR "worldview" OR "willingness to pay" OR "WTP" OR "willingness to consume" OR "WTC" OR "accept*" OR "concern*" OR "familiarity" OR "trust*" OR "label*") AND TS=("food*") NOT TS=("mouse" OR "rat" OR "arabidopsis" OR "mosquito")*

TS=("genetically modified organism" OR "GMO" OR "gene modifi*" OR "gene* engineer*" OR "biotech*") AND TS=("perception*" OR "belief*" OR "attitude*" OR "opinion*" OR "view*" OR "worldview" OR "willingness to pay" OR "WTP" OR "willingness to consume" OR "WTC" OR "accept*" OR "concern*" OR "familiarity" OR "trust*" OR "label*") AND TS=("food*") AND TS=("Australia*" OR "Queensland" OR "New South Wales" OR "Victoria*" OR "Tasmania*" OR "Australian Capital Territory" OR "Northern Territory" OR "South Australia*" OR "Western Australia*" OR "New Zealand") NOT TS=("mouse" OR "rat" OR "arabidopsis" OR "mosquito")*

3.2.3 Grey literature searches

In parallel with the searches in the scholarly databases, a search for relevant grey literature[1] was also conducted. Here we sought explorations of human responses to NBTs and/or GM in Australia or New Zealand. Considering the limited number of grey literature records on human responses to NBTs, grey literature from outside the Australian and New Zealand context was also included (e.g., van Mil et al. 2017 and Caputo et al. 2020). Grey literature was located through keyword searches on Google (e.g., 'NBTs', 'gene editing', 'genetic modification', etc), searches of the publication pages of relevant websites (e.g., the Office of the Gene Technology Regulator and the Australian National Centre for the Public Awareness of Science), and explorations of the citations in relevant literature.

3.3 Processing for inclusion

Database records generated by searches in Scopus and Web of Science using this strategy (1130 records) were then screened generously (see above note on minimising false negatives) at the title level for processing for inclusion in an Endnote bibliography. 449 records were selected as potentially relevant. In Endnote, 132 duplicates were then removed, leaving 317 records. Articles were then screened generously at the abstract level for final inclusion. 144 articles were removed as irrelevant to

[1] Grey literature is material not published in the traditional scholarly press, such as government reports, theses, research reports and some conference proceedings. Grey literature can range from very high quality to low quality work; while it is typically not peer-reviewed, that is not a definitional rule.

the review, and 173 selected for final inclusion. Of these, 3 papers were found to be unavailable after all document delivery options were exhausted, or were not in English, leaving 170 available for processing.

From the grey literature searches, 31 papers were added. Figure 3 maps this screening flow.

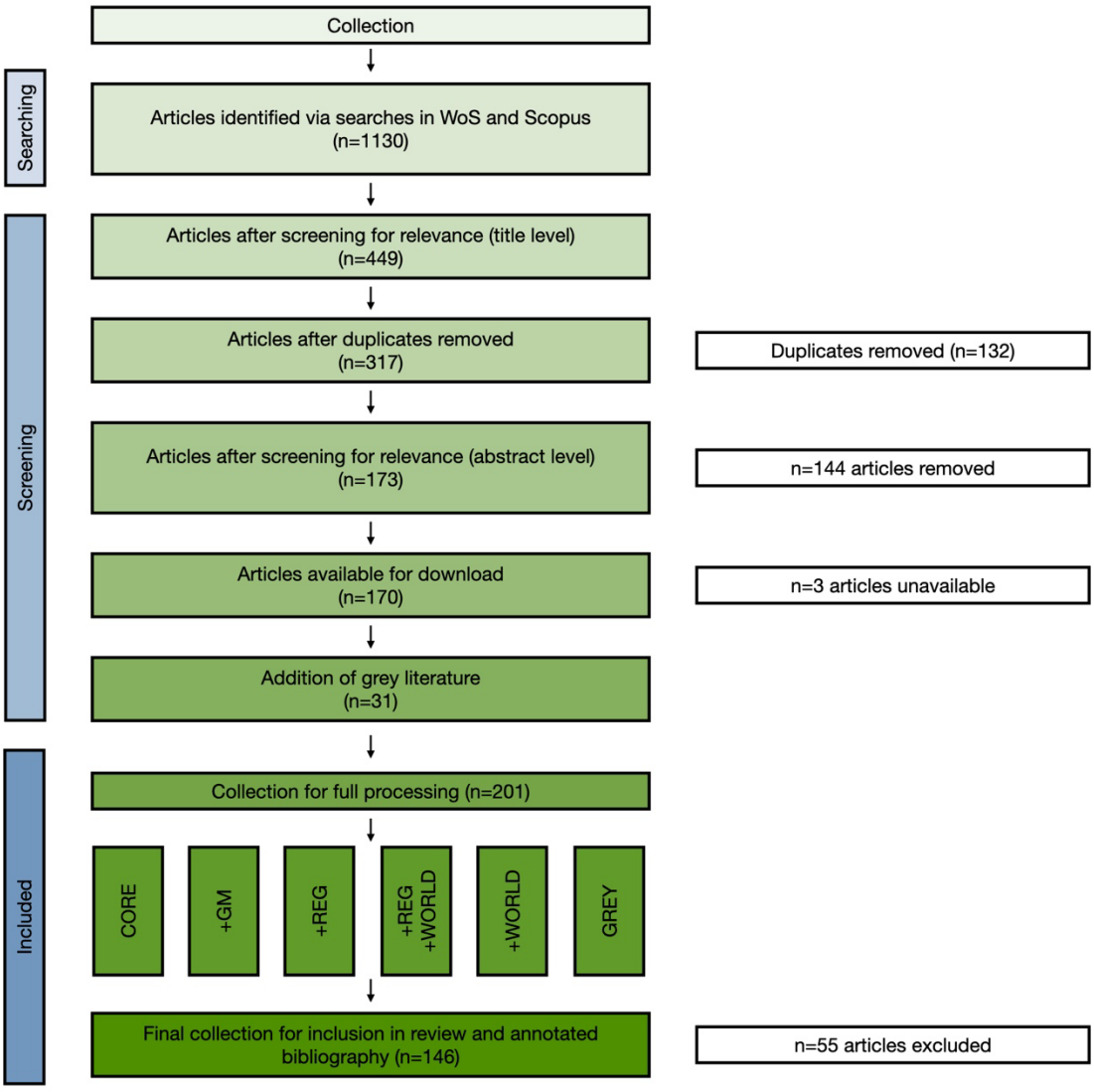

Figure 3 PRISMA type diagram mapping article screening

Section 4.1.2 below provides a summary of the literature processed for this review across a range of different types of categorisations.

Of these final 201 papers, 55 were excluded on full reading, as not relevant to the final review. Papers typically excluded at this stage addressed topics close to the scope of the review, but on closer inspection were deemed to be outside of our rigorous inclusion criteria. Examples include Lupton and Turner's "'I can't get past the fact it is printed': Consumer attitudes to 3D printed food', which included the keyword 'novel food technologies' and was conducted in Australia, but did not address NBTs or GM (Lupton and Turner 2018); Brent et al.'s 'Regulation of genetically modified foods in Australia and New Zealand', which spoke to the regulation of GM in Australia and New Zealand, but didn't cover human responses or NBTs in particular (Brent et al. 2003); and Olofsson et al.'s 'Attitudes to gene technology: The significance of trust in institutions', which explored attitudes to GM food, but not in Australia or New Zealand (Olofsson et al. 2006). This final type (which we considered, following our included category terminology, as +GM+WORLD) made up the bulk of the exclusions at this stage.

This review strategy left 146 papers in the final review, which are included in the annotated bibliography and which were analysed in detail (see section 4.1.2). One hundred and eleven of these were empirical or offered new data, 35 were either discussion, synthesis or opinion.

3.4 Data extraction

Following download, papers were then processed using Covidence (covidence.org), an application designed for processing systematic reviews.

Data extracted from each paper included metadata (e.g., publication type, whether peer-reviewed or not), method (e.g., method of research, sample size, location of sample), a summary of results according to the review questions (segmented by knowledge and awareness, attitudes, risk perceptions, behavioural responses, and underlying factors that influenced acceptance), and an assessment of quality and relevance to the review based on the systematic review guidelines of the Joanna Briggs Institute Manual for Evidence Synthesis (Aromataris 2020) and applicability to the review questions (see section 3.4.1 below for details). A full list of data extraction questions is included in the Appendix.

All papers were initially read by one coder for data extraction; key papers (i.e., those assessed as high quality, high relevance, medium quality, high relevance or high quality, or medium relevance) were read by two or three coders (see 3.4.1 below for quality and relevance assessment protocols).

Details from the data extraction were then used to compose the narrative review (section 4), and the annotated bibliography (section 5), as per section 3.4.3 below.

3.4.1 Assessment of quality and relevance

Questions asked in the process of this assessment (Aromataris 2020) were:

- Is there congruity between the research question or objectives, the research methodology and philosophical (theoretical) perspective, the methods used to collect data, the representation and analysis of data, and the interpretation of results?
- Do the conclusions drawn in the research report flow from the analysis or interpretation of data?
- In experimental or quantitative studies, is it clear what is the 'cause' and what is the 'effect', and that correlation is not being interpreted as causation?
- In experimental or quantitative studies, were any comparisons made between participants who were similar?
- In non-empirical or opinion papers, is the source of the opinion clearly identified and has standing in the field of expertise?
- In non-empirical or opinion papers, does the stated position result from an analytical and logical process that is made transparent in the paper?

Answers to these questions, along with the sample size and whether the paper was peer-reviewed, were used to generate an overall assessment of quality, as either high, medium, or low.

'Low quality' papers typically generated negative responses to one or more of the above questions (e.g., by making comparisons between dissimilar samples, using a sample not representative of a wider population, or offering conclusions beyond the scope of their evidence), were not peer reviewed, were based on a small or potentially inadequate sample size, or some combination of all. Ten records were assessed as low quality.

'Medium quality' papers typically addressed most (if not all) of the above questions and met the requirements for peer review and adequate sample size, but perhaps missed one element, or were drawn from a smaller sample than might would be needed to generate more representative findings. It should be noted that the 'medium quality' categorisation was used for a plurality of the papers, not to signal lack of endorsement but to permit separation of these from the truly high-quality papers that met all criteria. Eighty-five papers were assessed as medium quality.

Finally, 'high quality' papers addressed all of the questions above as well as peer review and sample size requirements, and offered particularly astute contributions to the literature. Fifty-one papers were assessed as high quality.

Relevance was assessed based on the contribution of the paper to addressing the research questions, combining the original scoping categories (CORE, +WORLD, +REG, +REG+WORLD, and +GM), whether the paper provided new data or new insights drawn from human participants, and the degree to which the data or insights focused on NBTs used in food.

Low relevance papers were typically from the +GM category, were discussion or editorial, or touched only briefly on NBTs in food. Forty-three papers were assessed as low relevance.

Medium relevance papers typically provided new data or insights, but with less focus on attitudes toward NBTs in food. Many in this category primarily focused on how attitudes contributed to pathways to regulation. Seventy-nine papers were assessed as medium relevance.

Finally, high relevance papers contributed directly to the core questions of the review. Twenty-five were assessed as high relevance.

3.4.2 Composing the annotated bibliography

Data recorded in Covidence for each paper were summarised and edited for inclusion in the annotated bibliography.

Key study details (such as type of literature [scholarly or grey], format [journal article or other], genre [empirical or other], method, participants, and country of focus) were reported for each record. As per 3.4.1, quality questions drawn from the Joanna Briggs Institute Manual for Evidence Synthesis (Aromataris 2020) were summarised to permit simpler and easily actionable articulations of the criteria of quality and relevance.

Separate review questions useful for internal data processing (e.g., about what the paper contributed to our understanding of attitudes toward NBTs or knowledge of NBTs) were collapsed to make a more readable summary, listed under each paper as key findings.

3.4.3 Composing the narrative review

Data extracted from each paper were used to compose the narrative review. Here key papers (i.e., high relevance papers of high or medium quality, and medium relevance papers of high quality) were re-read by a second (or for particularly important papers, third) coder to clarify and extract key results according to awareness, knowledge, attitudes, and behavioural responses to NBTs in food. It is important to note that many key papers provided insights or data on a range of aspects relevant to this review, such as on awareness, knowledge, *and* attitudes, so resisted simple categorisation as exclusively belonging to one of these categories.

Key results were then grouped in relevant sections and subsections, and turned into narrative prose. Additional data was gleaned from the other papers (high relevance papers of low quality, medium relevance papers of medium and low quality, and low relevance papers of high, medium or low quality) on a case-by-case basis, where insights, opinions or data allowed richer understanding of particular elements of the narrative.

Non-empirical papers were also included in a case-by-case basis in the narrative review. Here insights that helped frame, contextualise and unpack the meaning of empirical papers proved particularly useful. A number of non-empirical papers also provided insight into the thinking of advocates on particular sides of the issue.

4. Narrative review

4.1 Introduction

This section describes the results of the review of scholarly and grey literature. These results are presented as a narrative arranged thematically according to the research questions.

Overall, there are very few peer-reviewed, scholarly articles that explore the awareness, attitudes, or behavioural responses of consumers in Australia to NBTs (i.e., papers coded as CORE), and none that include consumers from New Zealand. Hence this narrative includes studies that examine these responses to NBTs in other countries (i.e., papers coded as +WORLD).

4.1.1 The literature at a glance

Following the scoping, searching, screening, and processing steps detailed above,146 papers of low, medium, or high relevance, were included in the final review and annotated bibliography.

One hundred and eleven of these were empirical or offered new data; 34 were either discussion, synthesis, or opinion; and one was a methods paper attached to another paper.

Of the 146 papers, 14 were assessed as high quality, high relevance; 32 as high quality, medium relevance; and 9 as high relevance, medium quality. Table 1 articulates the intersection of quality and relevance categories. To provide a brief overview of some of the key literature underpinning this review, Table 2 provides a summary of the 24 highly relevant papers. Tables 3, 4 and 5 provide summaries of the literature drawn on for each section of the review below.

		Quality		
		Low	Medium	High
Relevance	Low	8	30	5
	Medium	1	46	32
	High	1	9	14

Table 1 Number of papers by quality and relevance

							Does this paper say anything about consumers' ... of/to NBTs					
Short citation	**Type of literature**	**Target**	**Methodology**	**Sample size (if includes ANZ just ANZ numbers provided)**	**Main location of sample (if ANZ included says ANZ)**	**(Main) Human factor**	**Awareness and knowledge**	**Attitudes**	**Risk perceptions**	**Behavioural responses**	**Does this paper say anything about factors which influence acceptance of NBTs?**	**Journal**
Britton & Tonsor 2019	Scholarly	Food animals	Quantitative	1000	US	Willingness-to-pay				Yes	Yes	Food Quality and Preference
Caputo et al 2020	Grey	Multiple	Mixed methods	1000	US	Willingness-to-pay	Yes	Yes		Yes	Yes	(report)
Cormick & Mercer 2017	Grey	Other / General	Mixed methods	1000	Australia	Attitudes	Yes	Yes			Yes	(report)
Cormick & Mercer 2019	Grey	Other / General	Mixed methods	1000	Australia	Attitudes	Yes	Yes			Yes	(report)
Critchley et al 2019	Scholarly	Food animals	Quantitative	1000	Australia	Acceptance	Yes	Yes			Yes	Frontiers in Genetics
Debucquet et al 2020	Scholarly	Other/ General	Qualitative	0-99	Europe	Acceptance		Yes	Yes		Yes	Public Understanding of Science
De Marchi et al 2019	Scholarly	Food plants	Quantitative	500-999	Europe	Willingness-to-pay				Yes		Science of the Total Environment
Edenbrandt et al 2017	Scholarly	Food plants	Quantitative	500-999	Europe	Willingness-to-pay				Yes	Yes	Journal of Agricultural Economics
Edenbrandt 2018	Scholarly	Food plants	Quantitative	500-999	Europe	Willingness-to-pay				Yes	Yes	British Food Journal
Farid et al 2020	Scholarly	Multiple	Quantitative	100-499	Japan	Attitudes	*	*			Yes	International Journal of Environmental Research and Public Health
Ferrari et al 2020	Scholarly	Multiple	Quantitative	100-499	Europe	Attitudes	Yes	Yes	Yes		Yes	British Food Journal
Gatica-Arias et al 2019	Scholarly	Food plants	Quantitative	1000	Costa Rica	Attitudes	Yes	Yes	Yes	Yes	Yes	Plant Cell, Tissue and Organ Culture
Kato-Nitta et al 2019	Scholarly	Food plants	Quantitative	1000	Japan	Attitudes		Yes	Yes		Yes	Palgrave Communications
Kilders & Caputo 2021	Scholarly	Food animals	Quantitative	1000	US	Willingness-to-pay				Yes	Yes	Journal of Agricultural Economics
Marette et al 2021	Scholarly	Food plants	Quantitative	100-499	Europe	Willingness-to-pay	Yes	***		Yes	Yes	Appetite
Muringai et al 2019	Scholarly	Food plants	Quantitative	1000	Canada	Willingness-to-pay	**			Yes	Yes	Canadian Journal of Agricutural Economics
Shew et al 2017	Scholarly	Food plants	Quantitative	100-499	Australia	Willingness-to-pay				Yes	Yes	Food Control
Shew et al 2018	Scholarly	Food plants	Quantitative	100-499	Australia	Willingness-to-pay	Yes		Yes	Yes	Yes	Global Food Security
Son & Lim 2021	Scholarly	Food plants	Quantitative	100-499	Korea	Willingness-to-pay	Yes		Yes	Yes	Yes	International Journal of Environmental Research and Public Health
van Mil et al 2017	Grey	Multiple	Mixed methods	1000	UK	Attitudes		Yes	Yes		Yes	(Report)
Yang & Hobbs 2019	Scholarly	Food plants	Quantitative	500-999	Canada	Willingness-to-pay				Yes	Yes	American Journal of Agricultural Economics
Yang & Hobbs 2020a	Scholarly	Food plants	Quantitative	500-999	Canada	Willingness-to-pay				Yes	Yes	Journal of Agricultural Economics
Yang & Hobbs 2020b	Scholarly	Food plants	Quantitative	500-999	Canada	Attitudes		Yes	Yes		Yes	Journal of Food Products Marketing
Yunes et al 2019	Scholarly	Food animals	Mixed methods	500-999	Brazil	Acceptance		Yes	Yes		Yes	PLoS ONE
Yunes et al 2021	Scholarly	Food animals	Qualitative	500-999	Brazil	Acceptance		Yes	Yes		Yes	Sustainability

*measured (according to method) but not reported
**measured knowledge of GM but not gene editing
***authors use the term attitudes, but only WTP data is presented

Table 2 A summary of highly relevant papers

4.1.2 Use of terms/terminology

We began this review with a broad definition of NBTs, and some of the key tools and typologies regularly categorised as such. However, in the process of this review, it became evidence that some terms are used inconsistently or are poorly defined within the literature discussed below.

Cisgenesis, for example, is used in several papers explored below, and often described as a 'new' biotechnology. However, this term refers only to the source of the novel genetic material, rather than the process used to transfer it. Importantly, cisgenic organisms can be derived via 'traditional' GM techniques such as agrobacterium-mediated or biolistic transformation, as well as via NBTs (De Marchi et al. 2019). In a number of the studies discussed below, information about particular processes was not provided to participants, and so it is difficult to assess whether the findings relate to NBTs or cisgenic GM.

More prosaically, the term 'GE' is also used in range of different ways, namely to denote either gene editing, genome editing, or genetic engineering.

Throughout the review below, we have used the clearest version of the terminology utilised by the original authors, adding clarification where necessary. For example, where the authors have used 'GE' we have replaced with their specific definition, whether gene editing, genome editing, or genetic engineering; where the authors have explored responses to cisgenesis, we have reported on their definition of the term. Importantly, this means that not all results, and even those based on outwardly similar methods, are necessarily as comparable as they might at first seem.

These issues also point to a wider communication challenge. As evident in the annotated bibliography below, researchers in this field are exploring a range of related concepts that can be considered NBTs, but are not always clear about what they mean. While this might frustrate and challenge those working within this space, it should be noted that these difficulties could become significantly more problematic when engaging wider public audiences. If we are to engage with public audiences on these issues in this complex domain where meanings can become unclear and diffuse due to different experiences, knowledge, and understandings, then it is best that we are as clear as possible at the outset about what we mean.

4.2 Awareness and knowledge of NBTs

Key findings: people, in general, know less about NBTs than GM; Australia shows little difference in awareness as compared to other countries (and data is unavailable on New Zealand); and education is likely to increase awareness and knowledge.

This section explores what is known about awareness and knowledge of NBTs, and factors that influence awareness and knowledge of NBTs.

Short citation	Target	Methodology	Sample size (if includes ANZ just ANZ numbers provided)	Main location of sample (if ANZ included says ANZ)	(Main) Human factor	Journal
Caputo et al 2020	Multiple	Mixed methods	1000	US	Willingness-to-pay	(report)
Cormick & Mercer 2017	Other / General	Mixed methods	1000	Australia	Attitudes	(report)
Cormick & Mercer 2019	Other / General	Mixed methods	1000	Australia	Attitudes	(report)
Critchley et al 2019	Food animals	Quantitative	1000	Australia	Acceptance	Frontiers in Genetics
Ferrari et al 2020	Multiple	Quantitative	100-499	Europe	Attitudes	British Food Journal
Gatica-Arias et al 2019	Food plants	Quantitative	1000	Costa Rica	Attitudes	Plant Cell, Tissue and Organ Culture
Marette et al 2021	Food plants	Quantitative	100-499	Europe	Willingness-to-pay	Appetite
Shew et al 2018	Food plants	Quantitative	100-499	Australia	Willingness-to-pay	Global Food Security
Son & Lim 2021	Food plants	Quantitative	100-499	Korea	Willingness-to-pay	International Journal of Environmental Research and Public Health

Table 3 Key literature drawn on in this section

It is worth observing that the literature on the factors that influence knowledge and awareness differs from that on actual knowledge and awareness (see Table 3). Typically, literature on factors that influence knowledge and awareness is more likely to be peer reviewed and published in the scholarly literature, and more likely to engage with a range of scholarly debates. In contrast, literature on knowledge and awareness itself is more likely to be grey literature, and less likely to engage with key scholarly debates. Moreover, it should also be stressed that research that addresses the influences on awareness or knowledge cannot inherently provide a proxy for research on awareness or knowledge, even if data is reported before and after an intervention. Typically this is a representativeness question: research done on predictors of awareness or knowledge is often done with smaller samples of convenience (e.g., university students), rather than with wider samples representative of a population of interest.

4.2.1 Awareness and knowledge of NBTs in Australia/New Zealand

Key findings: Knowledge and awareness of NBTs is low in Australia, and has not been explored in New Zealand.

Perhaps unsurprisingly, what is known about knowledge and awareness of NBTs in Australia is that as a whole, Australians know very little. While studies in this space have focused on self-reported perceptions of knowledge, most people report low awareness or knowledge of NBTs.

The earliest survey of awareness of Australian or New Zealand consumers to NBTs was undertaken for the Office of the Gene Technology Regulator (Cormick and Mercer 2017). This survey of 1255 Australians revealed that despite being a relatively new technology, 17% of respondents stated that they could explain it to a friend, 39% stated that they had heard of it but knew little or nothing about it, and another 39% stated that they had never heard of it.

Low knowledge was found by Critchley et al. (2019) in their 2017 survey of 1004 Australians.[2] On a scale of 0 = *I know nothing about gene editing* to 10 = *I know a great deal about gene editing*, mean responses were 2.8 (SD=2.57) for the 501 respondents who were surveyed via computer-assisted telephone interview) and 2.91 (SD=2.71) for the 503 surveyed via an online panel, suggesting that self-perceived knowledge is low.

Low levels of awareness were also found by Shew et al. (2018) in the only peer-reviewed study of Australian attitudes to NBTs in a food crop, where 12.6% of the 444 Australians they surveyed responded that they had specifically "heard of" CRISPR (note of course that the applicability of these results to NBTs generally is unclear).

In Cormick and Mercer's 2019 survey for the OGTR, 13% of respondents stated that they could explain it to a friend (a statistically significant decrease from 2017), 48% stated that they had heard of it but knew little or nothing about it (a statistically significant increase from 2017), and another 32% stated that they had never heard of it (a statistically significant decrease from 2017).

Although knowledge of "genetic modification" is higher than NBTs in Australia, it has been slowly decreasing over time (Cormick and Mercer 2019). Responses to "know enough to explain to a friend" for "genetic modification or GMOs" has dropped from 33% in 2015 to 30% in 2017 and 22% in 2019, while "have heard of it but know very little about it" increased from 48% in 2015 to 51% in 2017 and 56% in 2018. Similarly, Shew et al. (2018) reported that 68.2% of their respondents had "heard of" GM.[3]

4.2.2 Awareness and knowledge of NBTs in the international context

Key finding: Internationally, knowledge of NBTs is low, and lower than knowledge of GM.

Echoing the Australian findings discussed above, what is known about knowledge and awareness of NBTs in the international context is that knowledge and awareness are low, and consistently lower than that of GM.

Some potential country differences can be discerned. A small number of international studies have reported on knowledge and awareness of NBTs, mostly in the context of WTP studies (see section 4.4 for a description of the WTP data). One exception is a survey of knowledge and attitudes in Costa Rica (n=1018) where 3.7% of the interviewees had heard or read a little (1.9%), some (1.2%), or a lot (0.6%) about gene editing via CRISPR/Cas9 (Gatica-Arias et al. 2019). All studies which made the comparison show that awareness and knowledge of NBTs is lower than for GM. In 2018, Shew and colleagues examined awareness of NBTs in a food crop (as well as WTC, see below) in the USA, Canada, Belgium, France, and 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%). In this study, Australians had the second highest awareness of GM (68%) behind Canada, and the second-lowest awareness of gene editing, behind France.

Echoing Shew et al.'s (2018) broad picture of lower awareness of NBTs, Son and Lim surveyed 200 Korean adults in 2019, finding 85% had heard of GM, and 45% had heard of gene editing (Son and Lim 2021).

Ferarri and colleagues (2020) showed greater knowledge of GM than gene editing amongst the 234 Millennials and Gen Z-ers they surveyed in Belgium and the Netherlands. Self-reported knowledge of gene editing (on a scale of 1 = low and 5 = very high) had a mean of 2.48 (SD=1.27) for all respondents compared with a mean of 2.85 (SD=1.27) for GM.[4]

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[2] Though this study focused mainly on the acceptability medical applications, it did include some questions and discussion on food animals. Of the 1004 respondents, 501 were surveyed via a computer assisted telephone interview (CATI), and 503 via an online panel (OLP). The two groups were not significantly different (at $p < 0.05$) in terms of state and territory, gender, and political association, although the CATI sample was older, more educated, more multicultural, more likely to be retired, and more spiritual.

[3] These findings could, perhaps, indicate a reduction in the socio-political salience of GM, such that fewer feel either a drive to know about GM, or possess a motivated reasoning based confidence in that knowledge. However, confidence in that assessment would require further evidence.

[4] Significance of difference was not reported.

Caputo et al. (2020) surveyed 4,487 US shoppers, distributing them across different information treatment groups.[5] Of the 1289 participants that did not receive any information prior to surveying (i.e., the control group), 63% had some knowledge of GM (combining 'heard and knows a lot about it' and 'heard and knows a little about it'), while 31% reported similar knowledge of gene editing.

Between country comparisons are rare, but in Shew et al. (2018) we see that knowledge of CRISPR was highest in the US (with 20% of respondents having heard of it) and lowest in France (10.2%). Marette et al. (2021) found a similar picture, with 66.9% of US participants aware of 'food innovations and biotechnologies' including gene editing, compared with 46.3% of French participants.

4.2.3 Understanding of NBTs

Key finding: In the absence of information, non-experts don't conceptually separate NBTs from other technologies.

In almost all of the empirical studies examined in this review, participants were provided with some definition of a new breeding technique in an attempt to discriminate knowledge of NBTs from GM. This limitation in experimental design makes it very difficult to determine whether consumers consider NBTs and GM technologies as similar. A novel study by Debucquet et al. (2020) used a free-sorting task in with French consumers (n=45) to determine lay understanding of NBTs, GM, mutagenesis, and epigenetic techniques. The task used a 'book' metaphor, and deliberately avoided the use of technical terms that might polarise views. Participants tended to sort the techniques in one of two ways in an almost 50:50 split. The first clustering was based on what the authors refer to as "Cartesian logic" and “randomness" of the change, that is whether the technique involved no modification, targeted/controlled modification, random changes due to external factors (mutagenesis), or random changes due to direct manipulation of the DNA (cisgenic/transgenic GM). The second clustering, referred to as "naturalistic logic" by the authors, was based on the amount of "exogenous DNA" involved in the manipulation. In this latter group, conventional cis/transgenesis and SDN-3-mediated[6]genome editing techniques (SDN-1 and SDN-2)[7]. Interestingly, the latter clustering most closely resembles the recently amended *Gene Technology Regulations 2001 (*Cth). Debucquet et al.'s (2020) findings are discussed further in sections below. s (2020) findings are discussed further in sections below.

4.2.4 Sources of information

Key finding: Key sources of information include internet search and television; key government institutions are considered trustworthy by a majority of people.

The 2019 survey by Cormick and Mercer (2019) indicated that a general internet search was the main source of information about gene technology in Australia (44%), followed by documentaries on television (38%), news stories on television (31%), and current affairs shows on television (25%). The authors note that "despite concerns about social media as a source of information or misinformation on gene technology, it rated at 11% or less for respondents" (68). Interestingly, this survey also revealed that information source preferences and trust are not necessarily closely aligned, as television documentaries were rated the most trustworthy. Unfortunately, these data do not discriminate between NBTs and older gene technologies.

With respect to organisations as information sources, Cormick and Mercer (2019) found that the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the National Health and Medical Research Council (NHMRC) were considered trusted sources of information about gene technology by the highest percentages of participants (67% and 66% respectively). FSANZ was a close

[5] The treatments varied according to the types of information that participants were given, as well as the products that consumers were asked to evaluate. The questions related to knowledge and beliefs were asked after the discreet-choice experiments to evaluate willingness-to-pay, and after they'd been given different types of information about the benefits of gene editing. Hence we are reporting only data from the control group.

[6] Site-directed nucleases (SDNs) can be used to create a break in the DNA as a specific site that can be allowed to repair randomly (SDN-1), repair in a controlled, pre-determined way (SDN-2) or two include a section of DNA in the repair (SDN-3) from the same or closely related species (cisgenic) or an unrelated species (transgenic).

third with 61% of participants. Those organisations considered trustworthy by the least number of participants were industry groups (27%) and overseas regulators (19%).

4.2.5 Factors influencing awareness and knowledge

Key finding: Education and age appear to influence awareness and knowledge; gender appears not to influence.

Research focusing on GM has previously reported a number of socio-economic factors as being associated with levels of awareness and knowledge. Our review has found few studies that report on the relationship between knowledge of NBTs and these socio-economic factors (as described below). Socio-economic factors are more likely to be reported in studies to describe participants and to demonstrate that they are representative of the populations being studied.

Gender differences in knowledge of GM has been frequently reported in the literature (see Ankeny and Bray 2016; Bray and Ankeny 2017 for an overview of this literature). In their 2019 survey, Cormick and Mercer (2019) found no significant differences in awareness of gene editing based on gender. Similarly, Gatica-Arias et al. (2019) found no significant difference between genders in knowledge of gene editing in their study in Costa Rica.

Educational differences have also been examined in relation to knowledge of GM (see Bray and Ankeny 2017 for an overview). Educational differences in knowledge about gene editing were shown by Ferrari et al. (2021). Those with a 'hard science' background had higher objective knowledge (assessed via true/false statements about biology and gene technology). A similar finding was reported by Gatica-Arias et al. (2019) in Costa Rica. While 3.7% of respondents (n=1018) had at least some knowledge of gene editing, this went up to 6.7% amongst those with a university education, and down to 3.4% with high school or 0.8% with lower education (Gatica-Arias et al. 2019).

Age appears to associate with knowledge, with younger people knowing more about NBTs. Ferrari et al. (2021) documented a higher self-reported knowledge of gene editing (n=234) amongst Gen Zers (mean of 2.76 on a scale of 1-5, SD=1.28) than Millennials (mean of 2.24 on a scale of 1-5, SD=1.21).

4.2.6 Importance of awareness and knowledge

Key finding: Awareness and knowledge of NBTs is low, but more work is needed to understand what kind of knowledge consumers want and need, and how this connects to other factors.

Studies that examine awareness are important for understanding the salience of particular issues and are useful for informing engagement strategies. However, having knowledge *of* a technology is very different to knowing *about* a technology or being deeply engaged in the issues associated with it. There is considerable debate in the literature 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 knowledge and beliefs will also be of central importance.

Most of the papers analysed in this review refer to participants' self-reported knowledge. That is, they ask participants to rate their own knowledge of NBTs or similar on a scale. Ferrari et al. (2021) and Caputo et al. (2020) also report 'objective' knowledge, assessed by scoring answers to bimodal, true or false statements. Both subjective and objective knowledge have been examined within the context of GM foods, with inconsistent findings about the relationship between type of knowledge and acceptance (see Ferrari et al. 2021 and Bray and Ankeny 2017 for an overview of these studies).

However, many of these studies are framed with acceptance or rejection as the end point, and more crucially, with acceptance as being the "correct" response. What is unclear from these studies is what knowledge is required for consumers to feel that they are adequately able to evaluate the risks, benefits, and other considerations to enable them to come to an informed decision about acceptance or rejection. For example in an examination of the effects of information provision within a GM context, Qin and Brown (2007) showed that although there were few changes in attitudes, participants felt more confident about their understandings of the impact of GM food on consumer choice and health (see section 4.4.4 for a discussion of NBT-related studies that examine the role of information). To provide another example of broader types of knowledge that might be relevant in this domain, Bruce and Bruce

(2019) note that knowledge of farming systems may be important for consumers to assess the animal welfare claims associated with gene edited livestock and hence evaluate risks and benefits (see also section 4.3.3).

The take-away from this strand of research is rather complex and does not provide us with clear guidance, since the apparent role and influence of knowledge about NBTs is deeply related to the framing and details of the particular research study. While the majority of the studies show some positive correlation between knowledge and acceptance, there are a few high-quality studies that are more equivocal. More research is needed particularly on broader types of knowledge that relate to people's understandings of NBTs beyond the biological details of how they work.

4.3 Attitudes, beliefs and perceptions toward NBTs

Key findings: In general, people appear more positively disposed toward NBTs than GM, and men and younger people appear more positively disposed than those from other demographics.

In between knowledge and behaviours sit a range of psychological, cognitive, and attitudinal human factors – including attitude, risk perception, acceptance and concern – that can be broadly grouped together. This section discusses what is known about these factors regarding NBTs in food.

Short citation	Target	Methodology	Sample size (if includes ANZ just ANZ numbers provided)	Main location of sample (if ANZ included says ANZ)	(Main) Human factor	Journal
Shew et al 2018	Food plants	Quantitative	100-499	Australia	Willingness-to-pay	Global Food Security
Son & Lim 2021	Food plants	Quantitative	100-499	Korea	Willingness-to-pay	International Journal of Environmental Research and Public Health
Caputo et al 2020	Multiple	Mixed methods	1000	US	Willingness-to-pay	(report)
Cormick & Mercer 2017	Other / General	Mixed methods	1000	Australia	Attitudes	(report)
Cormick & Mercer 2019	Other / General	Mixed methods	1000	Australia	Attitudes	(report)
Critchley et al 2019	Food animals	Quantitative	1000	Australia	Acceptance	Frontiers in Genetics
Debucquet et al 2020	Other/ General	Qualitative	0-99	Europe	Acceptance	Public Understanding of Science
Ferrari et al 2020	Multiple	Quantitative	100-499	Europe	Attitudes	British Food Journal
Gatica-Arias et al 2019	Food plants	Quantitative	1000	Costa Rica	Attitudes	Plant Cell, Tissue and Organ Culture
Kato-Nitta et al 2019	Food plants	Quantitative	1000	Japan	Attitudes	Palgrave Communications
van Mil et al 2017	Multiple	Mixed methods	1000	UK	Attitudes	(report)
Yang & Hobbs 2020b	Food plants	Quantitative	500-999	Canada	Attitudes	Journal of Food Products Marketing
Yunes et al 2019	Food animals	Mixed methods	500-999	Brazil	Acceptance	PLoS ONE
Yunes et al 2021	Food animals	Qualitative	500-999	Brazil	Acceptance	Sustainability

Table 4 Key literature drawn on in this section

In a similar way to what was observed in the literature on knowledge and awareness, the literature on the factors that influence attitudes differs from the literature on actual attitudes. Again, literature on factors that influence attitudes is more likely to be peer reviewed and published in the scholarly literature, and more likely to engage with a range of scholarly debates. In contrast, literature on attitudes themselves is more likely to be grey literature, and less likely to engage with key scholarly debates. Further, as noted previously with the literature on knowledge and awareness, research that addresses the influences on attitudes cannot be taken as a direct proxy for actual information on attitudes, even if data is reported before and after an intervention. Typically this issue arises because of lack of representativeness: research done on influences is often done with smaller samples of convenience (e.g., university students), rather than with wider samples representative of a population of interest.

4.3.1 Attitudes toward NBTs in Australia and New Zealand

Key finding: Although data is limited, Australians appear more accepting of food produced using NBTs than GM.

As with data on Australian knowledge of NBTs discussed above, our understanding of Australian attitudes to NBTs is limited. However, what can be gleaned suggests that attitudes may lean toward the positive. It should also be noted that while some data specifically differentiate NBT-type techniques from GM, many studies about gene technology and the resulting data on attitudes are technique-agnostic.

Cormick and colleagues' work provides a useful introduction. In their 2017 report for the Office of the Gene Technology Regulator (Cormick and Mercer 2017), 57% 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. These responses appeared marginally more positive than those received about GM, which was seen by only 46% of respondents as likely to improve our way of life. Seventeen percent of respondents, however, thought gene editing might make things worse, compared with the 26% who thought GM would make things worse. Similar acceptance numbers can be seen in Cormick and Mercer's follow up report (2019). Here 52% thought it might improve our way of life, while 19% thought it might make things worse.

When comparing different techniques, cisgenesis (defined by Cormick and Mercer 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 43% and 42% of people rating them as highly acceptable (7-10 on a 10-point Likert scale). Various transgenesis options ('introducing the genes of a plant of a different species' [32%]; 'introducing the genes of a bacterium' [22%]; 'introducing the genes of an animal' [22%]) were considered acceptable by fewer participants (Cormick and Mercer 2017). A drop in acceptability of gene editing (from 42% to 36%) was seen in 2019 (Cormick and Mercer 2019). Given these are the only studies available in the Australian context – and the only studies that provide a longitudinal picture – it is difficult to ascertain the validity of this small attitude shift, or reasons that may have caused it.

In reverse, levels of low acceptability (0-3 on a 10-point Likert scale) were highest for transgenic approaches using genes from the most distantly related donor species: using genes from animals had low acceptability for 35% of respondents, bacterium (24%), another species of plant (22%), 'switching genes on or off' (20%), gene editing (16%), and genes from the same species (13%).

4.3.2 Attitudes toward NBTs in the international context

Key finding: The international literature appears to mirror what is known in the Australian context: attitudes to NBTs appear generally more positive than those about GM

Surveys conducted by Ferrari et al. (2021), Gatica-Arias et al. (2019) and Kato-Nitta et al. (2019) all reveal attitudes to NBTs that are consistently positive, and more positive than attitudes toward GM. Ferrari et al., (2021) in their study of Gen Z and Millennial attitudes in Belgium and the Netherlands found what they describe as a "generally positive attitude toward [gene editing]". Overall, the mean average for pro-statements toward gene-edited food (M = 3.72 on a 5-point Likert scale, SD = 0.6) was significantly higher than for the anti-statements (M = 3.07, SD = 0.72). Yang and Hobbs (2020b), drawing on a survey of 697 Canadians, found higher acceptability of gene editing (M = 2.47 on a 6-point Likert scale, SD not reported) than transgenesis (1.95) or mutagenesis (1.64).

In their survey in Costa Rica, Gatica-Arias found high proportions of people who believed CRISPR foods would increase crop production in the country (66.0%), improve the economy (63.7%), and bring benefits to their families (60.7%) and the environment (57.4%). Similarly, 80.2% - 84.5% of participants would accept the use of gene editing for a variety of purposes. Nearly half of the participants perceived low or no risk to quality of life, health, or environment. Meanwhile, in their survey of 3197 adults in Japan, Kato-Nitta et al. (2019) found that their participants tended to have more favourable attitudes toward gene editing than toward GM, though such differences were much smaller than the differences between attitudes to conventional breeding and GM.

International comparisons are rare, but McFadden and Smyth (2019) observe that Europeans hold more negative perspectives on gene edited foods than their American or Canadian counterparts. In contrast,

Shew et al.'s (2018) American, Australian, Canadian and Belgian participants consider CRISPR safer than GM, but their French participants consider the technologies equally safe.

From a different perspective, Bakhtin et al. (2020) employed a semantic network mapping methodology (drawing on 30 million relevant scientific, media, government and international organisation documents sourced online) to gauge the clustering of emerging topics in food production. Their results suggest coverage of CRISPR and other new biotechnological methods appears less negative than GMOs, and various terms associated with NBTs (gene editing, CRISPR/Cas9) are becoming more prevalent in the corpus than older terms such as genetically modified organism.

4.3.3 Factors that influence attitudes toward NBTs

Key findings: The picture on factors that influence attitudes toward NBTs is not yet clear, though men and young people may be more accepting, and health and environmental benefits may generate greater acceptance

This section discusses the key factors found in the literature that influence attitudes toward NBTs. Here we consider the applications of the technology; sociodemographic factors; perceptions and worldviews; and communication.

First, it is apparent that what we use NBTs for matters.

For example, in their survey of 1004 Australians, Critchley et al. (2019) found that editing the genes of animals for food is typically less well received than using the techniques for improving human health, and for human and animal research. Gene editing for food production is, however, considered more acceptable than gene editing for human enhancement. While not necessarily on NBTs (their study included both GM and gene editing questions), Cormick and Mercer found a similar pattern of higher acceptability for the use of 'gene technology' for medical uses (~60% 2015-2019) than for food and crops (~35% over the same period) (Cormick and Mercer 2019).

Some have observed an interaction between personal / environmental considerations and acceptability. Here McFadden and Smyth note that "more than half (55%) of EU consumers support cisgenic application to reduce pesticide residue, compared with 33% support for a transgenic application" for pesticide reduction (2019: 450).

Others point to an interaction with animal welfare: in their survey of 570 participants from Southern Brazil, Yunes et al. (2019) found 56% considered gene editing an acceptable alternative to castration of male pigs.[7] However, in a second study (Yunes et al. 2021), the acceptability of using gene editing to produce polled (hornless) cattle was 33%, and improved muscle growth only 12%. Although the acceptability of gene editing in livestock production was increased by perceptions of benefits for animal welfare it was reduced when the perceptions of risks and benefits were unevenly distributed between animals, producers, consumers, and industry.

Others point to food security – McFadden and Smyth observe that "Americans have not found consumer-related benefits (e.g., improve nutritional content) or producer-related benefits (e.g., save farmers' time) overly desirable. The one exception to this is to help ensure that the USA remains food secure" (2019: 450).

However, while there is certainly some evidence that people do consider benefits when assessing food produced using NBTs, it is worth underscoring Van Eenannam and Young's argument 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; Debucquet 2020; section 4.4 below).

Second, there is evidence that key sociodemographic factors are related to attitudes toward NBTs, similar to older GM technologies, but the associations are inconsistent. Some studies report that men are

[7] Interestingly, in the study by Critchley et al. (2019), moral concern for the editing of animal embryos for the purpose of improving human food was absent, although there was low support for this application. The authors suggest that other factors, such as the concern for animal welfare, may override moral concern in this instance. It should also be noted that surgical castration is not routinely practiced in Australia (https://aussiepigfarmers.com.au/pigs/our-animals/elective-husbandry-procedures/)

more accepting of food produced using NBTs than women (e.g., Muringai et al. 2020), echoing an older pattern in attitudes to GM (e.g., Cormick and Mercer 2019). However, in a qualification of this finding, Yang and Hobbs (2020a), found that while 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 in attitudes to NBTs. Ferrari et al. (2021) found no gender differences in attitude to gene editing.

There is a similar pattern with age. Echoing findings in the GM literature, Cormick and Mercer found that support for gene editing decreases with age (2019: 40), though the effect appears reduced for NBTs. For example, 42% of those aged 16-30 consider gene editing ('making a small change to an existing gene within a plant, as is done in gene editing') acceptable (7-10 on a 10 point Likert scale), compared with 32% of those aged 51-75. This 10% gap appears smaller than that for modification 'by introducing the genes of an animal' (29% compared with 14% acceptable). Debucquet et al. (2020) found a cluster of younger people more likely to appreciate the 'targeted' nature of NBTs. In contrast, Ferrari et al. (2021) and Yunes et al. (2019) found no association between age and acceptability of gene editing.

Level of education or knowledge was not found to influence attitudes by Yunes et al. (2019), but Ferrari et al. (2021) did find that those educated in a 'hard science' background considered gene editing most acceptable. Debucquet (2020) found a potential pattern of more educated people leaning toward naturalistic thinking, in turn associated with a preference for traditional breeding techniques.

Interestingly, while Yunes et al. (2019) found few sociodemographic variables associating with acceptability of gene editing, they did find that participants who grew up in an agricultural environment had lower odds of considering gene editing acceptable to eliminate boar taint than those had never been involved with agriculture. Although the authors do not provide an explanation for this finding, it appears to be unrelated to 'knowledge' because participants were also asked whether they currently lived in rural areas, or whether they were directly involved in pig production, and neither of these factors were associated with acceptability. The authors do state that there were concerns among participants that related to the introduction of "costly biotechnologies on family farms" (p.12) and hence these attitudes may be more to socio-economic factors associated with GM crops.

Third, echoing the GM literature, consumer values appear likely to affect attitudes toward NBTs.

For example, Yang and Hobbs (2020a), in their exploration of the role of cultural values (Kahan 2012) in shaping consumer acceptance of gene editing, found that those with hierarchical rather than egalitarian worldviews (respecting so-called 'social elites' such as scientists and regulators) were more likely to accept GM techniques, although this relationship did not hold for gene editing or using an edible coating to prevent browning. On an individualist-communitarian scale, it appears that those holding a communitarian worldview (placing a higher value on social as compared to individual welfare) are relatively more accepting of gene editing. Positive attitudes toward science and technology, and perceptions that biotechnology presents greater benefits than risks made acceptance of the use of gene editing and GM in food products more likely.

In their focus group explorations of attitudes to NBTs, Debucquet et al. (2020) found two attitudinal groupings: those who followed a 'Cartesian logic', who had more confidence in the 'targeted techniques' associated with NBTs, and those who used a 'naturalistic logic', who had a more positive perception of random techniques, which they perceived as more in line with natural mechanisms.

Ferrari et al. (2021) found consumers with more concern about the environment were less willing to accept gene edited foods. Interestingly, the authors had hypothesised that "because of the environmental benefits that this technology could generate … it could be reasonably supposed that consumers that are concerned about the environment would be more likely to accept [gene edited] food" (p.1278). (It should be noted here that this potentially 'optimistic' framing of gene editing / NBTs represents a problematic bias in the literature, discussed in greater detail in sections 4.3.4 and 4.5).

In this mix a variety of communication interventions have been explored as potentially influencing attitudes toward NBTs. Here some have raised arguments based on expertise and experience; others have sought to collect data on what might actually change attitudes.

Yang and Hobbs (2019), for example, explored the impact of communication interventions on preferences for novel food attributes and technologies, finding that information format (logical-

scientific versus narrative) matters: narratives help reduce negative perceptions regarding agricultural and food technologies, though they don't appear to be considered more trustworthy or credible. Others (Cormick and Mercer 2019; *Nature* 2021; Pirscher and Theesfeld 2018) have suggested that the ways we frame NBTs will play a crucial role in shaping attitudes into the future. Here some have argued that elements of the key framings of NBTs – as offering simpler, faster, cheaper and untraceable or 'nature-identical' pathways to produce genetically modified organisms – are unlikely to be seen by all audiences in a positive light (see Pirscher and Theesfeld 2018, Bruce 2017). More will be discussed on this below (section 4.4.4).

4.3.4 Importance of attitudes toward NBTs

Key finding: The literature has suggested attitudes to NBTs are more positive than GM, but it is not yet clear if this finding is reliable.

It is clear from the literature that people have generally more positive attitudes to NBTs than older GM technologies, despite having relatively low knowledge about them. It appears that both the 'less random' and 'less foreign' aspects of NBTs when compared with older GM technologies may be driving these attitudes but, as identified previously, it is unclear whether this is because people perceive this themselves or because this is the information that has been provided to them in studies or the way in which the studies have been framed. This point is critical: optimism about NBTs appears implicit in some of the literature explored in this review (see for example Ferrari et al 2021, Barrangou 2020, Wolter and Puchta 2017, De Marchi et al. 2019). Hence findings about positive attitudes may not be entirely well founded. Most of the research does not disentangle people's historical associations with language, concepts, and controversies associated with GM and its applications, as compared to their likely lack of pre-existing views about NBTs. It is also less clear whether NBTs are seen as 'less risky' or whether another factor is involved.

Some sociodemographic factors appear to influence attitudes, but more work here is needed. The proposed application of gene technology, and the context in which the application sits, clearly matters to consumers, and hence these factors may be important for both public engagement and regulation.

4.4 Behavioural responses

Key findings: Consumers appear to discount food produced using NBTs, but not as much as GM. This finding may, however, require more testing in wider contexts and as it intersects with values.

Knowledge and attitude will, of course, contribute significantly to long-term consumer responses to NBTs. But when it comes down to it, food is about eating: understanding behavioural responses to NBTs is essential. This section explores what is known.

Short citation	Target	Methodology	Sample size (if includes ANZ just ANZ numbers provided)	Main location of sample (if ANZ included says ANZ)	(Main) Human factor	Journal
Britton & Tonsor 2019	Food animals	Quantitative	1000	US	Willingness-to-pay	Food Quality and Preference
Caputo et al 2020	Multiple	Mixed methods	1000	US	Willingness-to-pay	(report)
De Marchi et al 2019	Food plants	Quantitative	500-999	Europe	Willingness-to-pay	Science of the Total Environment
Edenbrandt et al 2017	Food plants	Quantitative	500-999	Europe	Willingness-to-pay	Journal of Agricultural Economics
Edenbrandt 2018	Food plants	Quantitative	500-999	Europe	Willingness-to-pay	British Food Journal
Kilders & Caputo 2021	Food animals	Quantitative	1000	US	Willingness-to-pay	Journal of Agricultural Economics
Marette et al 2021	Food plants	Quantitative	100-499	Europe	Willingness-to-pay	Appetite
Muringai et al 2019	Food plants	Quantitative	1000	Canada	Willingness-to-pay	Canadian Journal of Agricutural Economics
Shew et al 2017	Food plants	Quantitative	100-499	Australia	Willingness-to-pay	Food Control
Shew et al 2018	Food plants	Quantitative	100-499	Australia	Willingness-to-pay	Global Food Security
Son & Lim 2021	Food plants	Quantitative	100-499	Korea	Willingness-to-pay	International Journal of Environmental Research and Public Health
Yang & Hobbs 2019	Food plants	Quantitative	500-999	Canada	Willingness-to-pay	American Journal of Agricultural Economics
Yang & Hobbs 2020a	Food plants	Quantitative	500-999	Canada	Willingness-to-pay	Journal of Agricultural Economics

Table 5 Key literature drawn on in this section

Willingness-to-pay (WTP) studies make up approximately 50% of the empirical studies involving human participants identified by this review (see Table 2). This suggests far less emphasis in the literature overall on research to underpin public engagement, such as exploring understandings, values etc, and more emphasis on research to identify whether people are more likely to purchase gene edited products than GM products. However, some of the WTP studies below do provide insight into product attributes that are important to consumers.

Most, if not all, of the WTP studies compared food products developed with NBTs with unmodified counterparts as well as products prepared with older GM techniques; some also compared NBT developed products with other novel food technologies. Most studies show that NBTs are discounted less than GM products, but more than unmodified products.

4.4.1 Behavioural responses to NBTs in Australia and New Zealand

Key finding: As with work on attitudes to NBTs, the literature on behavioural responses to NBTs in Australia and New Zealand is spotty; indications do suggest a discounting of NBT-derived food, but not as much as GM food.

Shew et al.'s 2018 investigation into WTP for GM and CRISPR-derived glyphosate-resistant rice in five countries is the only study that examines WTP in Australia or New Zealand. Interestingly, this study is one of the few that does not show a significant difference between the two technologies in any country, although the discount in Australia was slightly more. This result may be due to the glyphosate-resistance trait not being highly desired by consumers. This paper also showed that WTC for the two technologies in Australia was not significantly different, and 51% of respondents indicated they would consume both the GM and the CRISPR products. Overall, thinking that GM was safe, or thinking that they had eaten a GM food in the past week, had a significant positive influence on their WTC for CRISPR and GM. Familiarity with GM had a positive effect on CRISPR and GM WTC in Australia. Overall, the main drivers of WTC were perceptions of safety and environmental helpfulness and previous experience (i.e., having eaten GM). Demographics had little effect.

4.4.2 Behavioural responses toward NBTs in the international context

Willingness-to-pay (WTP) studies suggest that consumers prefer foods produced with NBTs over GM-produced food, but preferred them less than conventional foods.

Most of the WTP studies in the international context focus on plant-based foods. Interestingly, apples feature in three papers, most likely because several apple varieties have been developed through cisgenic techniques (De Marchi et al. 2019; Marette et al. 2021; Yang and Hobbs 2020).

De Marchi et al.'s (2019) examination of WTP was motivated by the potential for genetic technologies to reduce agriculture's impact on the environment, although they did not examine WTP for apples modified to have reduced environmental impact. Participants had to choose between apples that were produced either conventionally or through cisgenic breeding (participants were not told whether this was derived through GM or NBTs), as well as apples with either a brand or no brand and differing in country of origin. In this experiment, the participants segmented into an "attentive class" (37% of participants) who evaluated all attributes of the apples before making a decision and had a significant negative preference for cisgenic food when compared with conventional food. The second group comprised 54% of participants and were described as "technology indifferent", as they ignored the attributes related to the technology used and chose apples based on brand and country-of-origin, suggesting that these consumers may be indifferent to production technologies. The third "technology driven" group comprised 8.6% of the sample population, and seemed to only refer to the technology attribute when choosing apples; they also preferred conventional over cisgenic apples.

In the second WTP paper to examine apples (Marette et al. 2021), French and US consumers were asked to choose between non-browning apples derived through traditional hybridisation techniques, gene editing, and GM. Initially, participants were offered a choice between a standard apple (i.e., one that browns after cutting) and a new variety with non-browning characteristics developed through conventional means. US consumers were willing to pay more for the new variety, while French consumers were willing to pay less. Consumers from both countries discounted gene edited apples less than GM apples, although more than the conventionally developed variety, and US consumers discounted less than French consumers for both GM and gene edited varieties.

The third paper to examine apples (Yang and Hobbs 2019) also looked at WTP for non-browning apples, but also included an option for enhanced antioxidant levels. They examined WTP based on the apples being produced by either gene editing, GM, or an edible coating, and also examined the effects of information framing (see section 4.4.4 below for further discussion about information treatments in WTP studies). All three technologies were discounted by consumers when compared to conventional apples, with gene editing being discounted the least, and GM discounted the most. In their follow up work, Yang and Hobbs (2019) found a slight preference for gene editing (12.3%) over GM apples (9%): the resistance to gene editing technology appears to be significantly weaker than to GM and an edible coating, suggesting a ‘window of acceptance’ may be available in which to provide constructive, positive communication about this new technology.

This trend, namely that WTP for NBTs is less than for conventionally produced foods, but more than for genetically modified foods, extends into processed foods as well. In a Canadian study (Muringai et al. 2020) consumers had lower WTPs for frozen French fries produced using genetic technologies (GM cisgenic/intragenic, GM transgenic, and gene editing) as compared to French fries produced from potatoes bred by conventional methods, with WTP for GM transgenic lower than GM cisgenic, which was lower than gene edited.

In Denmark (Edenbrants 2018) consumers were less negative about bread produced with cisgenic rye than bread produced with transgenic rye, but more negative about cisgenic bread than bread produced with conventional rye. They still had negative value for bread produced with transgenic rye when the bread was also pesticide-free, but valued a cisgenic pesticide-free product positively. Frequent organic consumers did not differentiate between cisgenics and transgenics breads.

Given the strong resistance to genetically modified animals used for food, many animal production scientists hope that NBTs will be found more acceptable, particularly as NBTs may be used to endow animals with characteristics which may be beneficial for their welfare (Yunes et al. 2021), in addition to traits that can reduce the environmental impacts of animal agriculture. However, the research on this point to date is inconclusive. In a study examining WTP for milk, Kilders and Caputo (2021) found that

there was a positive WTP for gene-edited animal products when marketed with animal welfare benefits as a central strategy. This study asked consumers to choose between milk from horned cattle, conventionally de-horned cattle, and cattle that had been gene edited to be polled, and included an information treatment that included framing gene editing as promoting animal welfare. However, in a study by Britton and Tonsor (2019), consumers required a discount to be willing to purchase beef steaks derived from RNAi technology. In this study, participants were not provided with information about the purpose of the modification, but were given short phrases of supplementary information about RNAi with different framings, such as "basic and not biased", "historical", "promising and already used", and "concerned and caution" (190). For comparison with the RNAi treatment, consumers were also offered beef steaks produced using antibiotics as an example of another controversial technology. Across most of their treatments, the discount was less negative for RNAi than for antibiotic use (the exception being where there was no claim about antibiotic use on the label).

4.4.4 A note on information provision experiments within WTP studies

The effect of information provision has already been mentioned in section 4.2.6. Within the 13 WTP studies, five use an "information treatment" of some sort (Britton and Tonsor 2019; Caputo et al. 2020; Kilders and Caputo 2021; Marette et al. 2021; Yang and Hobbs 2019). Some of the information treatments relied on variations of short statements (less than 100 words) such as the following description of gene editing from Marette et al. 2021:

> These new "hybrid" apples, which keep longer and do not turn brown, can also be obtained from a technological innovation, which involves modifying the gene sequence of conventional apples, without the introduction of a foreign gene.
>
> This innovation consists of editing the genetic sequence of the apple in order to isolate the gene responsible for browning so that it can then be neutralized or deleted.
>
> Apart from the previous characteristics, these new apples are equivalent to apples from conventional agriculture and which have not been the subject of this innovation, especially in terms of nutritional intake and value.

Marette et al. (2021) provided similar statements for all of the products within the choice experiments, but the information was also varied between a short statement (example above) and a longer statement that included the addition of the following sentence:

> More specifically, it is a technique called CRISPR-Cas9, which has become a genetic engineering tool that makes it easier and more precise to modify DNA sequences.

Importantly, these treatments do not only differ in length, but also in content given the inclusion of the words 'genetic engineering' in the longer statement. Hence we disagree with the authors' interpretation of the results, namely that French consumers prefer longer messages, and that varying the length of the information did not impact US consumers.

Britton and Tonsor (2019) used four different short statements about RNAi with different framing ('basic and non-biased', 'historical, promising and already used', and 'concern and caution') in addition to a combination of product claims on labels ('free from', 'used', and no claim). The authors found no effect of the information treatments on WTP for meat produced with RNAi, but they did find an effect of the labelling claims, suggesting that having no wording about a controversial attribute will have a positive effect on WTP.

Caputo et al. (2020) used a combination of labels with production claims (e.g., gene edited, organic) and benefit claims, with the benefit claims (i.e., benefits to consumers, environment, or farmers) forming the basis of treatment groups, with no benefit claim as a control. Participants were exposed to these claims before completing surveys related to belief and knowledge, and found that the control group scored lower in the objective knowledge scale, where 42% of the control group agreed with the statement "GMO (bioengineered) foods are the same as gene-edited foods", while across the other information treatments less than 34% of respondents provided the "wrong answer" (70). Similarly, they found that participants who received only basic information perceived more risks than those who were given information about the environmental benefits of gene editing.

Although these findings suggest that providing information about gene editing, in particular about the benefits that it may confer, promotes acceptance of products produced with gene editing, we advise

caution in extending this conclusion to efforts at community engagement about gene editing. Another interpretation of these findings is that participants are simply using the information provided within the experimental settings to answer questions, relying largely on recall, rather than being able to engage more deeply with the issues.

In contrast, the paper by Yang and Hobbs (2019) does provide some useful insights for framing communication about NBTs. They compared the WTP for gene edited and GM apples with a non-browning and antioxidant trait but also varied the way in which information was provided to participants. Although WTP was significantly larger for both gene editing and GM for participants that were allocated information presented in a narrative style (first person) as compared to those that were allocated information in a logical scientific style (similar to a government report), participants' WTP for gene editing was significantly higher for those who, when given a choice, chose the logical scientific information. The authors suggest that the scientific style may be more important for new technologies than the type of technology.

4.4.5 Considering behavioural responses to NBTs

It is clear from the variety of WTP studies that consumers prefer foods produced with NBTs over GM-produced food, but less than conventional foods.

This finding is useful for certain purposes, but it should be recognised here that WTP cannot be taken as a simplistic proxy for acceptance or attitudes. Food choices are highly contextual. Country of origin (De Marchi et al. 2019; Edenbrandt et al. 2017), for example, appears to shift behaviours more than type of production technique.

Moreover, the preponderance of studies of this type suggests a desire on the part of producers to test the market before scientific investment. This approach may be a sensible business strategy, but ignores the fact that consideration of going to market might be premature. We would suggest that engagement and deliberation on uses of these techniques and more attention to how they are communicated to consumers might be prudent, before considering and testing market acceptance.

4.5 Conclusion

In this systematic literature review, we have summarised, assessed, and synthesised the available evidence on the awareness and knowledge, risk perceptions and attitudes, and behavioural responses of consumers to the use of NBTs in the production of food. To do this we have conducted a systematic search for relevant peer-reviewed and grey literature, finding 146 studies of varying relevance to the question at hand. One hundred and eleven of these were empirical or offered new data; 35 were either discussion, synthesis, opinion, or other.

Our key findings have been noted throughout each section; here we seek to summarise and reflect on three broad points.

4.5.1 A limited literature

Firstly, the relevant literature in this space is limited, and the literature that does exist is riven with gaps and methodological, framing, and other biases.

When it comes to knowledge, awareness, and attitudes, we do not have as much rigorous and longitudinal Australian data as might be desired. Moreover, a range of key questions regarding the influences on attitudes and behaviours remain unanswered.

There is a preponderance of work on consumers' WTP for food produced using NBTs (see section 4.4). While this work is certainly of value, it does suggest that the questions so far asked about NBTs for food production are primarily about consumer WTP and acceptance (see 4.2.6), and less about underlying values, policy considerations, or the broader context within which people come to understand technologies such as NBTs. There also exists some evidence of a potential positivity bias amongst the existing research, which may colour key findings (see section 4.3.4 and below).

Given these findings, it is important to note that better practices for engagement and communication on this issue require more rigorous research that explores the intersection of values and responses to NBTs, including what people want to know, who or what they have confidence in as sources of information, and in what ways they wish to obtain information or be engaged about NBTs in food production.

4.5.2 Responses appear slightly more positive toward NBTs than GM

Despite the limitations of the existing evidence, our second key finding is clearly supported in the literature: attitudes (see section 4.3) and behavioural responses (see section 4.4) to NBTs are slightly more positive than toward older forms of GM, though slightly more negative than food produced using traditional breeding techniques.

It appears that the 'more targeted' and 'less distant' nature of NBTs compared with more 'random' and 'distant' GM techniques is considered positively by consumers, though the data here rests on only a few studies.

However, it should be stressed that more and better quality evidence is required: it could be the case that this relative positivity toward NBTs appears as a result of the framing biases of the research thus far conducted (see section 4.3.4). It could also be a finding that evolves or vanishes as the prospect of food produced using NBTs becomes more real.

4.5.3 Communication matters

Thirdly, given the relative paucity of data, methodological biases in the literature (see sections 4.2.6 and 4.4.4 on information provision), and relatively low existing awareness of NBTs (see section 4.2), ongoing discussion and communication about food produced using NBTs will significantly shape attitudes into the future.

Three aspects of this point can be seen in the literature discussed in this review, and in the wider literature on public engagement on science and technology.

The first is that framing is crucial. While some research has suggested consumers appreciate the potentially 'targeted' nature of NBTs (see Debucquet et al. 2020), and producers appreciate the

potential for 'simpler', 'faster', 'cheaper' and 'untraceable' pathways to produce GM organisms,[8] others have suggested that these key aspects may present critical communication challenges (Pirscher and Theesfeld 2018). For example, lack of traceability due to the production of 'nature-identical' GM organisms', may not be the socio-political success that its supporters hope it to be. For those who consider any technological intervention into DNA to be a boundary transgression, lack of traceability makes the prospect of gene editing worse, not better, than older GM. In such thinking, lack of traceability could be considered synonymous with being unmonitorable, stealth, or potentially even insidious (see Pirscher and Theesfeld 2018).[9] Similarly, the possibilities of being faster, cheaper, and easier might resonate with supporters of NBTs such as Barrangou (2020), but will these supposed advantages trump over developing processes for the discussion, engagement, monitoring, and regulation that many consumers may well demand? It is worth recalling Cormick et al.'s finding (2017) that the intervention most likely to change the minds of those who considered GM too risky were long term (i.e., 10 year) studies of safety. Bartkowski et al. (2018) provide an interesting discussion along these lines. Even further, there are some who worry that even the potential animal welfare advantages made possible by NBTs might bring negative side effects, such as further agricultural intensification (Bruce 2017; *Nature* 2021).

Others point to the key role played by labelling as a communication intervention. Bartowski and Baum (2019) note that this strategy can be closely coupled with deliberation (discussed below), in what they term an 'exit-voice' framework. Here deliberation allows 'voice', and labelling allows those reluctant to consume food produced by NBTs to 'exit' the market. Bechtold (2018) argues that food labelling and consumer choice should be considered as institutions to "support communication about values and to broaden the perspective on the agricultural use of genome editing and its products". Labelling, in this case, could "stagger the processes of deliberation allowing for cautious governance of the new breeding technologies" (see also Bechtold et al. 2018; Carson 2019).

A central argument, then, has emerged from this literature and related work on emerging technologies. Deep processes of public deliberation, dialogue, and discussion are needed that acknowledge culture, values, frames, and history. In a recent editorial in the journal *Nature,* it is argued that decisionmakers must "consult thoroughly and globally" (*Nature* 2021); similarly Pirscher and Theesfeld (2018) call for a "continuous discourse with society". This builds on earlier research from Schibechi and Harwood (2007) who argue that decisionmakers should be wary of a deficit model of community involvement and Wheen's older analysis (2004) which suggests such deliberation should take account of cultural and social issues. When considering what would be required for such a dialogue, values, context, and economic framings have been offered as essential components. Bechtold (2018) argues that deliberation about values is essential, and should be decoupled from considerations of risk. Similarly, Bray and Ankeny (2017) argue for "a more sophisticated and broader engagement about GM, against the backdrop of more complex considerations of values". Myskja and Myhr (2020) and others (e.g., Small 2005; Knight and Clark 2014; Knight 2016) offer the beginnings of economic framing for thinking about issues of value. Finally, it should also be observed that any deliberation cannot be removed from history: discussions will take place in political contexts that will recall earlier, and oftentimes fractious, debates on GM. As Van Eenennaam and Young (2018) note, the public discussions around the first gene edited food organisms will affect discussions about new technologies and food long into the future.

[8] These facts are applauded throughout the wider literature on NBTs, particularly in editorials and opinion pieces, and appear evident in the 'optimism bias' discussed in section 4.3.4 (see other examples in Barrangou 2020, Wolter & Puchta 2017).

[9] At this point it can be noted that untraceability may not be as perfect as some might hold. As Pirscher and Theesfeld (2018) note, to date conventional analytical methods such as PCR (polymerase chain reaction) cannot detect a modified product, but it has been argued (Kim and Kim, 2016) that CRISPR/Cas can leave small amounts of foreign DNA in the genome, rendering the resultant organism in some sense traceable.

5. Annotated bibliography

Aerni, P. (2010). Is Agricultural Biotechnology Part of Sustainable Agriculture? Different Views in Switzerland and New Zealand. *AgBioForum*, *13*(2), 158-172.

Study details: Scholarly literature, Journal article, Empirical, Other / General (target), Mixed methods, Survey (0-99 participants), New Zealand. High quality, low relevance.

Key findings: This paper compares attitudes of key agricultural stakeholders in New Zealand and Switzerland, finding that sustainability in New Zealand incorporates more 'progressive' thinking, such as precision agriculture, genetic engineering, and labelling. In Switzerland this sustainability is more 'defensive', focusing on direct payments, taxing food miles, and organic agriculture. Perhaps the most interesting finding for the present review is that the agricultural research organisations in New Zealand are more influential on stakeholder thinking than in Switzerland. Progressive attitudes regarding agricultural biotechnology in New Zealand (compared with Switzerland) appear related to the influence of innovative food research organisations and entrepreneurial producers' associations.

Ankeny, R. A., & Bray, H. J. (2016). "If We're Happy to Eat It, Why Wouldn't We Be Happy to Give It to Our Children?" Articulating the Complexities Underlying Women's Ethical Views on Genetically Modified Food. *International Journal of Feminist Approaches to Bioethics*, *9*(1), 166-191.

Study details: Scholarly literature, Journal article, Empirical, Other / General (target), Qualitative, Focus group (0-99 participants), Australia. High quality, medium relevance.

Key findings: This article explores women's attitudes and values associated with GM food. Argues that women's attitudes toward GM food is informed by their roles as professionals and caregivers. Women who had high scientific knowledge and were against GM often drew on their expertise to explain their concerns. Factors such as fat and additives were generally seen as more important than the presence of GM in foods. Many of the women who were concerned about GM foods were suspicious of multinationals (especially ownership of technology). Women who were concerned about GM foods considered GM to be a form of additive, whilst those women who were unconcerned did not consider GM to be a form of additive. Some women did not see GM food as being in conflict with natural food. Some women regarded GM as a risk to human health. Those women who were opposed to GM viewed herbicide tolerance as particularly problematic because of the additional side-effects around increased chemical use. Several of the women who were plant scientists believed that GM crops were more likely to be spray and pesticide-free. Some women were concerned about lack of safety testing of GM foods. The women who would consume GM foods were happy to also feed these to their children and guests. There was a correlation between ethical consumption and attitudes toward GM (i.e., caring for the environment and considering the needs of various communities were arguments made by those both for and against GM).

Araki, M., & Ishii, T. (2015). Toward Social Acceptance of Plant Breeding by Genome Editing. *Trends in Plant Science*, *20*(3), 145-149. https://doi.org/10.1016/j.tplants.2015.01.010

Study details: Scholarly literature, Journal article, Editorial / Opinion, Other / General (target). High quality, medium relevance.

Key findings: This editorial argues that a new global policy for new biotechnology is urgently required, filling the gap between process-based NBTs and product-based GMO regulations, and ensuring social acceptance of genome-edited crops. The authors argue that the time is right to gradually transition from process-based GMO regulations to product-based GMO regulations because many countries have had sufficient regulatory experience regarding conventional transgenesis since the early 1990s. Likewise, genome-edited crops should be regulated based on the end product after a comprehensive survey of off-target mutations has taken place. The authors propose that each country or international body, such as the Convention on Biological Diversity, should consider introducing regulatory standards according to stringent regulations that cover gain of function mutations, intragenesis, cisgenesis, and transgenesis initially because unanticipated health and environmental risks might result from plant breeding employing genome-editing technology. They argue we can reconsider mitigating the regulations toward deregulating all but transgenesis when sufficient regulatory experience has been gained regarding genome-editing crops. Such a cautious approach would contribute to harmonizing countries that regulate GMOs on a process basis with those that regulate on a product basis. The emergence of genome-editing should encourage us to reconsider the worldwide regulatory gaps regarding GMOs.

Bain, C., Lindberg, S., & Selfa, T. (2020). Emerging Sociotechnical Imaginaries for Gene Edited Crops for Foods in the United States: Implications for Governance. *Agriculture and Human Values*, *37*(2), 265-279. https://doi.org/10.1007/s10460-019-09980-9.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Qualitative, Media Study, US. High quality, medium relevance.

Key findings: This paper looks at how ‘pro' organisations frame gene editing through analysis of submissions to the US Food and Drug Administration. They find that the main framing uses sociotechnical imaginaries, along with the following frames: 1) GE (gene-edited food) is not GM, 2) GE (gene-edited food) will usher in a new green revolution, and

3) GE (gene-edited food) facilitates democratisation for agriculture and food. Consumer submissions were excluded from the analysis. They found that groups were trying to pre-emptively counter activist arguments about GMOs. May be useful in considering how terms of reference can limit discussions.

Bakhtin, P., Khabirova, E., Kuzminov, I., & Thurner, T. (2020). The Future of Food Production? A Text-Mining Approach. *Technology Analysis & Strategic Management*, *32*(5), 516-528. https://doi.org/10.1080/09537325.2019.1674802.

Study details: Scholarly literature, Journal article, Empirical, Other / General (target), Quantitative, Media study (1000+), Other location. Medium quality, medium relevance.

Key findings: This paper employs a semantic network mapping to gauge the clustering of emerging topics in food production. The corpus includes 30 million documents, including scientific articles from CrossRef database, United States Patent and Trademark Office (USPTO) patents, National Science Foundation (NSF) grant awards, news feed and media publications of influential media and sectoral organisations (Alexa and SimilarWeb tops of global news portals with a focus on science and technology, e.g., MIT Technology Review, businessinsider.com, venturebeat.com, techcrunch.com, etc.), and analytical reports of international organisations (e.g., Food and Agriculture Organization of United Nations [FAO], Organisation for Economic Co-operation and Development [OECD], etc.). Coverage of CRISPR and other new biotechnological methods appears less negative than for GMOs, suggesting the new terms might replace the old. CRISPR and other new biotechnologies do not appear directly connected to food security or the fight against hunger. GM is also not connected with food security. Uptake of NBTs needs to be understood within a range of key problems facing global food supply (e.g., food security, environmental damage) and other potential drivers and solutions (e.g., other food innovations), though this paper does not give a clear articulation of the pathways of influence.

Barrangou, R. (2020) Finding SECURE Ground: USDA Edits the Biotechnology Regulatory Framework. *CRISPR Journal*, *3*(3), 136-137. https://doi.org/10.1089/crispr.2020.29096.rba.

Study details: Scholarly literature, Journal article, Editorial / Opinion, Food plants. Medium quality, medium relevance.

Key findings. This editorial applauds the US Department of Agriculture's recent update to biotechnology regulations, arguing they "usher in a new era for the use and management of molecular breeding techniques for plants in general and commercial crops in particular... this is crucial at a time when food access, security, safety, and sustainability are most critical. This giant leap for USDA and smaller step for CRISPR opens the door for broader, more democratic use of these technologies. It also sets the tone for other countries and regulatory agencies to update their regulatory frameworks and policies... Exemptions are defined that apply to plants that have been modified with deletions (of any size), a single base-pair substitution, and introduction of sequences from within the plant's natural gene pool, as well as off-spring of genetically engineered plants that do not retain the GM of the genome-edited parent. The focus rests on the organism itself rather than the methods and technologies used to generate it, which is important given improvements in delivery and genome editing modalities over the past 33 years".

Suggests these exemptions will significantly reduce the burdens imposed by achieving regulatory approval in the old system: "Start-up companies in particular will benefit in many ways by not being burdened with the regulatory processes, including practical (conserving resources), financial (fewer requirements and paperwork), and time benefits, helping organizations demonstrate progress toward product development and commercialization between funding rounds".

However, notes that public trust must be built: "even after three decades of broad consumption (at least domestically in the United States) of GM crops and despite a plethora of scientific studies and reports documenting their safe use and consumption, there are still concerns about molecular breeding science, genome editing technologies, and products derived from these crops. This means we must do more to build consumer trust and highlight the benefits and value for food safety, sustainability, and environmental stewardship, while relying on science-informed policies and promoting transparency... The dialogue between regulators and breeders will continue under this framework and will evolve over time with petitions for 'non regulated' status and regulatory status reviews, but consumers often feel left out of the process, as illustrated by the mis-understood (and often misused) commentary period". Also calls for more studies articulating the risk and benefit differences between conventional and molecular breeding.

Bartkowski, B., & Baum, C. M. (2019). Dealing With Rejection: An Application of the Exit-Voice Framework to Genome-Edited Food. *Frontiers in Bioengineering and Biotechnology*, *7*(57), 1-15. https://doi.org/10.3389/fbioe.2019.00057.

Study details: Scholarly literature, Journal article, Discussion, Other / General (target). Medium quality, medium relevance.

Key findings: This article uses Hirschman's exit-voice framework to understand the contours of individual dissatisfaction and discontent related to novel genome-editing technologies. While not quantified, the paper does draw on literature pointing to dissatisfaction with GM technologies, and worries about genome-editing, in particular issues of naturalness, problem framing and patents and property rights. The paper presents the argument that "much dissatisfaction with and skepticism toward the biotech industry could... reflect the lack of effective recuperation mechanisms, whether exit or voice". While this is an entirely plausible framework for understanding the issue, little evidence is presented that can shift beyond the word 'could'. The paper does suggest that regulation that allows Hirschman's consumer 'exit-voice' response to the market can lead to governance approaches that might prevent problematic actions. This entails in particular the use of labelling as a means to enable 'exit' of consumers from

markets; and "far-reaching societal dialogue [and public deliberation] on the (perceived) benefits and risks of genome editing, rather than one that only seeks to find technocratic 'evidence-based solutions' (voice)".

Bartkowski, B., Theesfeld, I., Pirscher, F., & Timaeus, J. (2018). Snipping Around for Food: Economic, Ethical and Policy Implications of CRISPR/Cas Genome Editing. *Geoforum*, *96*, 172-180. https://doi.org/10.1016/j.geoforum.2018.07.017.

Study details: Scholarly literature, Journal article, Discussion. High quality, medium relevance.

Key findings: This paper provides a broad social science perspective on the implications of CRISPR/Cas genome editing for agriculture, and offer a conceptual view on socio-ecological-technical determinants relevant for CRIPSR/Cas-specific regulation. The authors argue that unique traits of the technology and its products become interwoven with new perceptions, new ethical considerations and new representations of the nature–technology boundary which then feedback on how society handles and implements this technology. "CRISPR/Cas is likely to have profound socio-economic consequences in the area of agricultural biotechnology as well as, generally, crop plant and livestock breeding. Especially, its emergence is believed to pose a significant challenge for current GM regulatory frameworks, particularly in the EU. It is very likely that due to CRISPR/Cas applications these frameworks will have to be reformed..." The approach of this paper is to discuss factors that should be taken into account when devising new, CRISPR/Cas-sensitive governance structures, without proposing specific changes to current regulations... Factors to consider include: the preferences of the relevant stakeholder groups (particularly (potential) consumers and producers of GM products); ethical issues related to CRISPR/Cas applications in the context of agricultural production; the characteristics of what CRISPR/Cas can achieve. "In other words, it is important to take into account what we (as society) want, what we should [missing word] and what we can." Describes four characteristics of CRISPR/Cas-related transactions that call for special attention when designing regulations: (1) non-traceability in the resultant organism, (2) the decentralisation of knowledge and use, (3) the uncertainty about off-target alterations, and (4) the speed of breeding.

Baumann, A., Osman, M., Burton, M., & Lumley, S. (2005). Understanding Western Australian Consumers' Views: Acceptance of Food Produced Using Gene Technology - A Case of Herbicide Tolerant Canola (Brassica napus L.). *Environmental Science and Pollution Research*, *12*(1), 56-56. https://doi.org/10.1065/espr2005.01.003.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Qualitative, Survey (100-499 participants), Australia. Medium quality, medium relevance.

Key findings: A survey of Western Australian acceptance of food produced using gene technology. Consumers who wanted GM canola oil to be labelled consider this their 'right'. They also wanted labelling so they can make informed decisions. On the other hand, those against labelling do not see any difference between GM and non-GM versions and those who were undecided reported having insufficient information to decide. Consumers tended to support labelling if they were sceptical of the health risks. On the other hand, consumers tended to be against labelling if they believed that there were advantages to GM crops (e.g., environmental benefits). Likewise, participants tended to be against banning GM crops if they considered GM crops to have agricultural/environmental benefits or if they produced healthier/more nutritious food. The vast majority (90.36%) of WA consumers wanted GM canola oil to be labelled. This compared to 5.36% which were against labelling and 4.29% which were undecided. The majority (72.38%) of participants also wanted GM crops/foods (including canola) to be temporarily banned in WA, whilst 27.62% were against the ban. Minimal information about research methodology (i.e., no demographic information about participants) and limited analysis of findings.

Baumuller, H. (2001). Genetically Modified Food in Australia: A Pilot Survey of Public Perceptions. *Food Australia*, *53*(8), 328-330.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Qualitative, Survey (0-99 participants), Australia. Medium quality, low relevance.

Key findings: Analysis based on interviews with Sydney university students. Participants were asked about six applications of GM: herbicide tolerant crops, food with increased nutrition, crops used for medicine, crops with increased yield, food with longer shelf-life, and crops adapted for certain conditions. Participants reported wanting the right to know and choose. Despite being in favour of public consultation and education, participants were generally unaware of existing efforts in these areas. Participants were generally willing to accept health risks if the application had sufficient benefits. Many participants were unaware of specific health risks. Health risks were often associated with specific applications rather than GM in general. Perceptions of health risks across different applications was also inconsistent and seemingly arbitrary (e.g., participants tended to view food with longer shelf-life as posing more of a health risk than other applications). Low usefulness as study is dated and also limited to university students; findings are inconclusive.

Bechtold, S. (2018). Beyond Risk Considerations: Where and How Can a Debate About Non-Safety Related Issues of Genome Editing in Agriculture Take Place? *Frontiers in Plant Science*, *9*(1724), 1-5. https://doi.org/10.3389/fpls.2018.01724.

Study details: Scholarly literature, Journal article, Discussion. Medium quality, medium relevance.

Key findings: This article presents a discussion on how genome editing in agriculture can be debated. It argues that the debate about genome editing is already risk-focused, and that the resulting confinement structurally hampers a sound discussion of the values that are at stake. In contrast, the paper argues that a comprehensive deliberation about values is needed in the context of genome editing in agriculture. Moreover, those deliberations should be separated from risk analysis and allow for individual decisions within our value system. However, the discussion of value arguments requires different procedures and different solution strategies than a scientific risk discussion. In this context, food labelling and consumer choice should be considered as institutions to support communication about values and to broaden the perspective on the agricultural use of genome editing and its products. Labelling, in this case, could stagger the processes of deliberation allowing for cautious governance of the new breeding technologies. While not the focus of the paper, the author believes that genome editing in food will be highly controversial.

Bechtold, S. N., Schleissing, S., & Durnberger, C. (2018). The GMO Debate Reloaded - A Survey on Genome Editing in Agriculture. In S. Springer & H. Grimm (Eds.), *Professionals in Food Chains* (pp. 341-346). Wageningen Academic Publishers. https://doi.org/10.3920/978-90-8686-869-8_53.

Study details: Scholarly literature, Conference paper / proceedings, Empirical, Other / General (target), Qualitative, Survey (0-99 participants), Europe. High quality, medium relevance.

Key findings: This article provides the results of a survey of German scientists and stakeholders in relation to freedom of choice and labelling of genome edited food. All participants had prior knowledge of genome editing or were familiar with innovative technologies more broadly. Medium usefulness as data was derived from scientists rather than consumers. Most participants were supportive of genome editing from an ethical standpoint. Points out that there were two primary viewpoints expressed by participants, namely the value of consumer sovereignty and food security as a major goal. When asked whether genome edited food should be labelled, 12 participants said no, 11 said yes, and 4 said maybe (total 27 participants). In the event of labelling being required for genome-edited food, participants believe that this labelling should be controlled by the state (this was true for those both for and against labelling). However, authors believe that state-controlled labelling would be insufficient to improve trust considering the criticisms which surrounded state-led GM labelling in Germany. A state-controlled labelling system could also prevent deeper engagement from occurring between consumers and producers. Authors argue that trust needs to be established between producers and consumers and a discussion needs to be had about objectives and responsibilities in the agricultural sector. They also argue that genome edited food should be labelled to provide consumers with freedom of choice. Also argues that consumers should be provided with information about genome editing which aligns with consumers' values and individual preferences (this includes information about the purpose of genome editing). In other words, this information should not be purely scientific in nature.

Biotechnology Australia. (2003), *Biotechnology Public Awareness Survey Final Report*. Millward Brown Australia.

Study details: Grey literature, Other report, Empirical, Other / General (target), Mixed methods, Survey (1000+ participants), Australia, High quality, medium relevance.

Key findings: This survey which occurred pre-NBTs, showed that knowledge of 'genetic engineering' had decreased a little from previous years, with 31% knowing enough they could explain to a friend (self-reported), and 80% of Australians expressed at least some level of concern. Perception of risk had increased from 2001 to 2003 to 64%. Likelihood of eating had decreased from 2001, "This was not long after September 11, so comments about global security trumpeting GM as an area of concern are interesting".

Biotechnology Australia. (2005a). *Public Awareness Research 2005 Overview.* Eureka Strategic Research.

Study details: Grey literature, Government report, Empirical, Other / General (target), Mixed methods, Survey (1000+ participants), Australia. Medium quality, medium relevance.

Key findings: This project presents data on Australian public awareness of, attitudes toward, and concerns about different applications of biotechnology, and the ways in which these drive public acceptance. Findings include moderate level of awareness of GM, compared with some other technologies (e.g., stem cells, fibre optics). Low levels of beliefs that GM would improve our way of life (46.5%, only cloning lower). Mean support for gene technology in food lower (4.9 on 10-point Likert scale) than health and medical (6.2). Gene technology in agricultural applications was perceived by many to be unnecessary, compared with medical applications. Usefulness and acceptability followed a similar pattern. Of GM crops, pest resistance was most useful, taste least useful, with a similar pattern for acceptability. Risk of food applications was perceived to be higher than medical (71.3% perceived gene technology for food to be risky, only 52.9% of people perceived gene technology in medicine risky). Respondents rated their confidence levels in using a range of products derived from genetically modified plants and animals such as plastics, fibres, building materials,

packaging, and fuel. Overall, as these products were not ingested, they were considered less of a risk to human health than GM food products.

Five key factors have been identified that underlie the public's acceptance of applications of biotechnologies. These are: Information – Information on what biotechnologies are and are not capable of, provided by a credible source; Regulation – Confidence that regulatory safeguards are in place to ensure the safety of the public and the environment; Consultation – A belief that the public has been appropriately consulted and given the opportunity for input into the development of biotechnology; Consumer choice – The ability of the consumer to either accept or reject each particular application of biotechnology; Consumer benefit – A perceived societal and individual benefit for each application.

Argues that public perceptions of these factors are as important as the reality.

Respondents had the least confidence in consuming food from genetically modified animals, followed by meat from animals fed GM stock feed, food containing a GM ingredient and GM fruit and vegetables.

Biotechnology Australia (2005b). *Public Awareness Research 2005: Regulation.* Eureka Strategic Research.

Study details: Grey literature, Other report, Empirical, Other / General (target), Mixed methods, Survey (1000+ participants), Australia. Medium quality, medium relevance.

Key findings: This report continues the sequence of biennial reports commissioned by Biotechnology Australia on Australian attitudes to biotechnology, using both exploratory focus groups and a nationally representative survey. This report focuses mostly on attitudes to regulation. The Federal Government (29.2%) was the source that was cited most often as being responsible for the regulation of gene technology in Australia, followed by the CSIRO (11.3%) and the Office of the Gene Technology Regulator (OGTR) (10.9%). A large proportion of respondents (43.1%) could not name any source that they believed to be responsible for regulation. Almost all respondents (93.5%) had heard of Australian Quarantine and Inspection Service (AQIS) and the majority (61.3%) was aware of Food Standards Australia New Zealand (FSANZ). Less than a third had heard of the other organisations listed, with OGTR (22.8%) being the organisation of which the fewest respondents were aware. The organisations that the greatest proportion of respondents trusted to regulate were the Australian Pesticides and Veterinary Medicines Authority (APVMA; 79.3%) and AQIS (79.2%). Approximately the same proportion of respondents said they trusted FSANZ (69.9%), OGTR (68.3%), and Biosecurity Australia (65.3%) to regulate gene technology. The majority (35% agreed and 43% agreed strongly) agreed that public consultation and participation improves regulation. A similar proportion (24% agreed and 27% agreed strongly) believed that farmers need to be GM-free to stay competitive, as believed that farmers need access to GM technology (31% agreed and 25% agreed strongly) in order to do so. A majority (35% agreed and 20% agreed strongly) agreed that we have to accept some risk from GM for Australia to remain competitive. Many felt unable to comment on whether Australia's current rules are sufficient (25%) and whether they are being followed (30%). Five key factors have been identified that underlie the public's acceptance of applications of biotechnologies. These are: Information – Information on what biotechnologies are and are not capable of, provided by a credible source; Regulation – Confidence that regulatory safeguards are in place to ensure the safety of the public and the environment; Consultation – A belief that the public has been appropriately consulted and given the opportunity for input into the development of biotechnology; Consumer choice – The ability of the consumer to either accept or reject each particular application of biotechnology; Consumer benefit – A perceived societal and individual benefit for each application.

Biotechnology Australia. (2007a) *Community Attitudes to Biotechnology: Report on Overall Perceptions of Biotechnology and General Applications.* Eureka Project 4001.

Study details: Grey literature, Other report, Empirical, Other / General (target), Mixed methods, Survey (1000+ participants), Australia. Medium quality, medium relevance.

Key findings: This report continues Biotechnology Australia's biennial examination of Australian attitudes to biotechnology. Knowledge echoes other reports, in that people claim more knowledge of IVF, cloning, and stem cell research than GM, which was rated above gene technology and biotechnology. The technologies that participants felt least knowledgeable about were gene technology and biotechnology. Twenty-two percent and 18% respectively indicated that they could explain these latter two technologies to a friend. Awareness of all technologies was high. More than nine in ten participants noted that they had at least heard of cloning, IVF, and stem cell research. Awareness of GM, gene technology, and biotechnology was slightly lower, at 87%, 79%, and 78% respectively. No significant changes from 2005 to 2007. Those who felt comfortable with new technologies expressed greater technology knowledge than those who did not feel comfortable; those participants who were university educated had greater self-assessed knowledge than those who were not; and finally, males were more likely to indicate being able to explain technologies to a friend than females. Of all technologies, participants were most likely to predict that stem cell research would have a positive future impact on our way of life. Indeed, almost nine in ten (87%) indicated that it would improve our way of life, while only 5% felt that it would make things worse. Predictions for gene technology and biotechnology were positive from the majority of participants, with 73% and 68% respectively signifying that these technologies would improve our way of life, and only a small number (10% and 8% respectively) predicting things being made worse. Positive future perceptions drop markedly for GM (45%) and cloning (28%), while negative future perceptions increased correspondingly (29% and 48%).

Those who felt more comfortable with new technologies had more positive outlooks for technologies in the future than others, males had more positive perceptions of cloning and GM than females, females had more positive perceptions of IVF than males, and lastly, those who are university educated and those aged 18-30 were more likely than others to predict that cloning will have a positive impact on our future way of life.

There was a small significant increase since last wave in the mean rating of support for the use gene technology in food and agriculture. The average rating given by participants in the current wave was 5.5 out of 10, while the average rating given in 2005 was 4.9. There was a notable increase in the proportion of participants rating themselves 'fully supportive' of gene technology in food and agricultural applications, from 6% in 2005 to 12% in 2007. There was a corresponding decline in the proportion of participants giving a support rating of 5 or lower. Only 8% of participants noted that they were 'completely against it'. Continued higher belief in the usefulness of gene technology for medicine (96%) compared with food crops (70%). The majority of participants (55%) expressed agreement that GM in agriculture was mostly for the benefit of commercial companies, with more than a third (37%) agreeing strongly. Continued higher risk seen in modifying genes for food (54%) versus medicine (37%). Highest levels of risk seen for GM involving the introduction of animal genes into a plant (73%), then bacterium (70%), another plant (52%), same species of plant (29%). Similar numbers for acceptability. Overall, 2005 to 2007 saw increased awareness (76% to 85%), increased usefulness (64% to 83%), decreased risk (71% to 54%), and increased acceptability (48% to 73%). There was an increase in WTC all food types, including GM, from 2005 to 2007. The purpose of biotechnology in agriculture, and of GM crops in particular, was perceived by many to be commercial, and as bringing benefit to large producers and big businesses rather than to consumers, farmers, or society generally. By contrast, the purpose of biotechnology in the medical realm was perceived to be altruistic and humanitarian, and as benefiting society as a whole. Some participants described feeling powerless to influence how biotechnology is used in agriculture, with many believing that the information they receive about food-production processes is insufficient and that food labelling requirements are inadequate. This is linked to the misconception that GM products are widely available on supermarket shelves. As a result, these participants believed they were unable to exercise choice as consumers. Acceptability of GM food crops was highest if labelled according with food regulation (38%); and lower if certified as safe by a government regulator (32%); developed by a government funded research body (32%); developed by an Australian company (31%); or developed by an overseas company (8%).

Biotechnology Australia (2007b). *Community Attitudes to Biotechnology: Report on Food and Agriculture Applications.* Eureka Project 4001.

Study details: Grey literature, Other report, Empirical, Other / General (target), Mixed Methods, Survey (1000+ participants), Australia. Medium quality, medium relevance.

Key findings: This report is a continuation of Biotechnology Australia's biennial investigations of attitudes to biotechnology in Australia. As with other reports, participants' self-assessed level of understanding was highest for IVF, with 59% indicating that they could explain the technology to a friend. One in two participants (50%) indicated an equivalent level of knowledge for cloning, while just over one in three (35%) did so for GM and stem cell research. The technologies that participants felt least knowledgeable about were gene technology and biotechnology. Twenty-two percent and 18% signified that they could explain these technologies to a friend respectively. Awareness of all technologies was high. More than nine in ten participants noted that they had at least heard of cloning, IVF and stem cell research. Awareness of GM, gene technology and biotechnology was slightly lower, at 87%, 79% and 78% respectively. Those who felt comfortable with new technologies expressed greater technology knowledge than those who did not feel comfortable, those participants who were university educated had greater self-assessed knowledge than those who were not, and finally, males were more likely to indicate being able to explain technologies to a friend than females. Very little changes in understanding or awareness 2005 to 2007. Of all technologies, participants were most likely to predict that stem cell research would have a positive future impact on our way of life. Indeed, almost nine in ten (87%) indicated that it would improve our way of life, while only 5% felt that it would make things worse. Predictions for gene technology and biotechnology were positive from the majority of participants, with 73% and 68% respectively signifying that these technologies would improve our way of life, and only a small number (10% and 8% respectively) predicting things being made worse. Positive future perceptions drop markedly for GM (45%) and cloning (28%), while negative future perceptions increase correspondingly (29% and 48%). Those who feel more comfortable with new technologies had more positive outlooks for technologies in the future than others, males had more positive perceptions of cloning and GM than females, females had more positive perceptions of IVF than males, and lastly, those who are university educated and those aged 18-30 were more likely than others to predict that cloning will have a positive impact on our future way of life. As with other studies, overall higher support for medical applications (avg 6.9 on 10-point Likert scale) than food and agriculture (5.5 on 10-point Likert scale).

Biotechnology Australia. (2007c). *Community Attitudes to Biotechnology: Report on Regulation*. Eureka Project 4001.

Study details: Grey literature, Other report, Other / General (target), Mixed methods, Survey (500-999 participants), Australia. Medium quality, medium relevance.

Key findings: This report continues Biotechnology Australia's biennial series of reports looking at attitudes to biotechnology regulation in Australia. Overall, the aim of this project was to update and further develop understanding of the community's awareness of, attitudes toward and concerns about different applications of biotechnology, and the ways in which these drive community acceptance. In addition, research aimed to understand community aspirations for biotechnology, information sources, and the success of current public information and awareness strategies.

Survey participants were initially asked, without prompting, to name any organisations that they believed were responsible for the regulation of gene technology in Australia. The large majority of participants were unable to mention any specific organizations that they believed were responsible for regulation of gene technology in Australia. By far, the most common response was 'don't know' at 48%. The only organization cited by more than a handful of participants was the CSIRO, mentioned by 12% of participants. The Federal Government was also cited by 12% participants, but no further information was provided regarding the department or agency assumed to be involved. A

very small number (less than 1% of participants) mentioned FSANZ, Biosecurity Australia, the Office of the Gene Technology Regulator (OGTR), the National Health and Medical Research Council (NHMRC) and Biotechnology Australia. Survey participants were subsequently asked whether they trusted organisation they had mentioned to regulate gene technology in Australia. Significant declines in trust were seen across the board between 2005 and 2007 - 79% to 64% for APVMA, 70% to 63% for FSANZ, 79% to 59% for AQIS and 65% to 48% for Biosecurity Australia.

Regarding attitudes to regulation, a large proportion of participants expressed no opinions on the rigorousness of the rules that regulate gene technology (30% neutral) or the extent to which these rules are complied with (31% neutral). There were almost equal proportions of participants who agreed (29%) and who disagreed (31%) that the rules that regulate the use of gene technology are sufficiently rigorous. However, there was slightly more agreement (33%) than disagreement (26%) that the rules that regulate the use of gene technology are complied with. It would seem therefore that people are more trusting of compliance than of regulation itself. There was strong agreement that public consultation and participation improves the regulation of gene technology (44% agreed strongly and 21% agreed somewhat) and only a small level of disagreement (6% disagreed strongly and 7% disagreed somewhat). Views on the influence of economic competitiveness on decisions relating to gene technology were very mixed. There were similar levels of agreement and disagreement for both statements, resulting in nett agreement close to zero (+5% and +4% respectively). There were also high proportions of 'neutral' responses (25% and 28% respectively), indicating participants' lack of decisiveness on this issue. The report concludes that at the present time and across the community, there is a noteworthy suspicion of government's role in the regulation of biotechnology and the relationship between government and big business, with a general distrust of politics carrying over into community attitudes on these more specific issues. Accordingly, the public needs reassurance that government regulation in this area is impartial and guided by input from stakeholders. At the same time, the community would like to see a reduced role for religious considerations in regulatory decision-making and an increased role for scientific expertise. Participants showed greatest concern for GM crops and foods (compared with other applications of biotechnology), therefore food and agriculture should be the focus of future communication about the regulation of biotechnology.

Bloomfield, B. P., & Doolin, B. (2012). Symbolic Communication in Public Protest Over Genetic Modification: Visual Rhetoric, Symbolic Excess, and Social Mores. *Science Communication*, *35*(4), 502-527. https://doi.org/10.1177/1075547012469116.

Study details: Scholarly literature, Journal article, Empirical, Food animals, Qualitative, Media study, New Zealand. Medium quality, low relevance.

Key findings: This article considers the protests through which a group of New Zealand women—MAdGE (Mothers Against Genetic Engineering in Food and the Environment)—enacted a campaign against GM in food. Some attitudes very opposed to GM food, though not quantified. For these people GM represented a clear boundary transgression. 10,000 people participated in a protest march against GM. While we can't gain any understanding of the depth or breadth of the concerns mentioned, it is useful to understand the extent to which the concerns raised by the anti-GM protest movement are not necessarily about GM in particular, but may stem more from concerns about boundary transgressions.

Bray, H. J., & Ankeny, R. A. (2017). Not Just About "the Science": Science Education and Attitudes to Genetically Modified Foods Among Women in Australia. *New Genetics and Society*, *36*(1), 1-21. https://doi.org/10.1080/14636778.2017.1287561.

Study details: Scholarly literature, Journal article, Empirical, Other / General (target), Qualitative, Focus group (0-99 participants), Australia. High quality, medium relevance.

Key findings: This paper seeks to understand Australian women's attitudes toward GM food, including the impact of different levels of science education. Participants who avoided GM foods and had less science education, described GM foods as unnatural and cited a lack of knowledge as their reason to avoid GM foods. Participants who avoided GM foods and had high levels of science education also cited a lack of evidence to prove the safety of GM for humans and the environment (they also viewed GM as counter to accredited and sustainable agricultural practices). GM was a relatively minor issue for participants compared to other food choices (i.e., natural, local, healthy and additive-free). All of the participants who were plant scientists were unconcerned about eating GM foods (GM was also considered to be valuable in terms of social good/environmental sustainability). Most of the remaining participants indicated that they would avoid GM food (this included some participants with high levels of science education). For some participants (esp. those involved in the production of GM crops), GM foods were not considered to be incompatible with natural food. Many of the participants viewed both product and process as important components of GM. Participants who were plant scientists showed support for GM foods as they believed that there was no evidence of harm from GM (whether scientific evidence or evidence from their own consumption). On the contrary, those participants with health science education opposed GM foods as they believed there was insufficient evidence of safety from testing of GM foods (these women also tended to be more concerned about the impact of GM food on themselves and their families; these women also tended to distrust large companies). Similarly, participants with little science education opposed GM foods as they believed that there was insufficient evidence of safety (although they were unable to pinpoint exact unknowns about GM foods).

Britton, L. L., & Tonsor, G. T. (2019). Consumers' Willingness to Pay for Beef Products Derived from RNA Interference Technology. *Food Quality and Preference*, *75*, 187-197. https://doi.org/10.1016/j.foodqual.2019.02.008.

Study details: Scholarly literature, Journal article, Empirical, Food animals, Quantitative, Experiment (1000+ participants), US. High quality, high relevance.

Key findings: This paper explores US consumer WTP for beef produced using RNAi techniques. Findings indicate negative consumer attitudes toward biotechnology like other studies. Results show respondents preferred either of the beef steak options over the option of no beef steak at all across all experiment designs. The WTP discount is largest when RNAi use is the lone attribute. The magnitudes are the smallest when USDA grade is present and become larger (less negative) when antibiotic use is present. This implies that consumers value a higher grade of beef steak, but they have negative perceptions of the presence of RNAi. WTP is larger (discount less negative) for RNAi use than antibiotic use. Acceptance of NBTs (in this case RNAi) appears to associate with price discount, and in context - people appear most willing to pay when other controversial attributes (antibiotics etc) are present in the market. Findings indicate a low demand for beef products derived from RNAi, which in the future, may be able to reduce production costs. How RNAi technology is framed on a food product label in comparison to other attributes present in the marketplace in the future will influence its market viability.

Bruce, A. (2017). Genome Edited Animals: Learning From GM Crops? *Transgenic Research*, *26*(3), 385-398. https://doi.org/10.1007/s11248-017-0017-2.

Study details: Scholarly literature, Journal article, Discussion, Food animals. Medium quality, medium relevance

Key findings: This paper looks at how genome editing of livestock has attempted to learn some of the lessons from commercialisation of GM crops, and takes a systemic approach to explore some of the complexity and ambiguity in incorporating genome edited animals in a food production system. It suggests that further investigation of interactions among stakeholders involved in livestock production is therefore important. One of the challenges of meeting public aspirations for welfare benefit is the difficulty of agreeing on what is a welfare benefit. What may seem beneficial, or at least neutral, in terms of animal welfare for those familiar with livestock production, can be more controversial for others. Public views on more profound changes to physiology, eg altering sex ratios, are as yet, largely unexamined. In general attitudes are likely to be influenced by the particular reason given for the application, how beneficial or risky it is considered to be, and specific context of application and the alternatives available. Early applications of genome editing in livestock have also focused on creating gene variants that exist in the same, or similar species, and seeking to avoid crossing species boundaries. Given the tendency among some people to conflate GM with transgenesis, genome editing might be thought to provide an opportunity to avoid the regulatory impasse that in many cases has been a feature of GM animals. However, avoiding regulation for genome edited animals on the basis that they do not involve crossing species barriers would restrict applications of genome editing only to those that meet this requirement, and could discourage many other developments. At the other extreme, avoiding any kind of regulation for genome edited animals could also easily result in a public back-lash. Some publics may see unregulated adoption of the technology as a way to introduce (by stealth) practices that they think are cruel or unnecessary. A carefully nuanced mechanism for identifying and regulating genome edited animals seems essential. Also suggests that attempting to avoid regulation is a dangerous path.

Bruce, A., & Bruce, D. (2019). Genome Editing and Responsible Innovation, Can They Be Reconciled? *Journal of Agricultural & Environmental Ethics*, *32*(5-6), 769-788. https://doi.org/10.1007/s10806-019-09789-w.

Study details: Scholarly literature, Journal article, Discussion, Food animals. High quality, medium relevance.

Key findings: Discussion paper which talks about responsible research and innovation (RRI). Looks at two applications of genome editing: hornless dairy cows and pigs resistant to porcine reproductive and respiratory syndrome. Argues that it is difficult to achieve RRI during the early stages of research. Instead, the application of RRI should occur once research has reached the proof of principle stage (i.e., before the particular application of genome editing has reached the market). Argues that the public's lack of knowledge about livestock agriculture is a key factor in shaping responses to genome editing.

Burton, M., & Pearse, D. (2002). Consumer Attitudes Toward Genetic Modification, Functional Foods, and Microorganisms: A Choice Modeling Experiment for Beer. *AgBioForum*, *5*(2), 51-58.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Quantitative, Survey (0-99 participants), Australia: High quality, medium relevance.

Key findings: Tests Western Australian consumers' WTP for conventional versus GM beer. 19 out of 64 participants (30%) consistently voted for conventional beer. Analysis is based on remaining participants who were willing to make trade-offs. Participants did not value the GM barley or yeast varieties which reduced production costs, but would purchase this product if there was a price discount (older participants required less of a price discount). Those participants who were not concerned about cholesterol viewed the GM yeast variety with health benefits as neither positive nor negative. However, those participants who were concerned about cholesterol viewed the health benefits positively and would be willing to pay a premium for this. Medium usefulness as study is somewhat dated.

Campbell, H., & Fitzgerald, R. (2001). Follow the Fear: A Multi-sited Approach to GM. *Rural Society*, *11*(3), 211-224. https://doi.org/10.5172/rsj.11.3.211.

Study details: Scholarly literature, Journal article, Empirical, Other / General (target), Qualitative, New Zealand. Medium quality, low relevance.

Key findings: This is an old paper that looks at the Royal Commission on GM in New Zealand and 'tracks the fear of GM food through several threads' in the forum. They examine how ignorance was constructed as the source of fear, as well as the context of other food scares such as Mad Cow, and the cultural significance of 'Frankenfoods'. Given its age and its lack of focus directly on consumers, this paper is not directly relevant to this review.

Campbell, Y., & Wheeler, H. (1999). *Public Attitudes Toward Biotechnology*.

Study details: Grey literature, Other report, Empirical, Other / General (target), Mixed methods, Survey (1000+ participants), Australia. Medium quality, low relevance.

Key findings: This report was commissioned by Biotechnology Australia to conduct a national survey of public awareness levels of and attitudes toward biotechnology and its applications. The objective of the research was to inform the development of Biotechnology Australia's public awareness and information program on biotechnology, and to establish a benchmark level against which awareness raising activities can be measured and evaluated. Just over one quarter of Australians had not heard of biotechnology (26%). Few people had not heard of genetic engineering (8%). Those people aware of biotechnology considered it would improve our way of life over the next 20 years (56%) rather than make things worse (6%). While 42% of Australians considered that genetic engineering would make our lives better over the next 20 years, over one third of Australians (34%) considered that genetic engineering would make our lives worse. Genetic engineering future impact 34% negative, 46% positive. The use of genetically modified products varied considerably based on the nature of the product. The majority of the people would wear clothes made from genetically modified fibre (81%), use genetically modified medicines (64%), eat oil/margarine made by genetic engineering so that it was healthier (57%) or buy genetically modified fruits or vegetables if they tasted better (51%). People were less likely to eat genetically modified meat (38%) or buy genetically modified fruits and vegetables that lasted longer (44%).

Caputo V., Lusk J., & Kilders V. (2020). *Consumer Acceptance of Gene Edited Foods: A Nationwide Survey on US Consumer Beliefs, Knowledge, Understanding, and Willingness to Pay for Gene-Edited Foods Under Different Information Treatments*. FMI Foundation.

Study details: Grey literature, Other report, Empirical, Multiple (target), Mixed methods, Survey (1000+ participants), US. High quality, high relevance.

Key findings: Analysis of survey in which US food shoppers were asked about their beliefs, knowledge, understanding and WTP for gene-edited foods. WTP for gene edited products increased as participants were informed of the benefits of gene editing (environmental and consumer benefits resonated more with participants than farmer benefits). Participants were willing to pay more for gene-edited vegetables than meat (WTP for vegetables was higher for fresh foods compared to processed foods). When asked to complete a word association task for gene editing, participants tended to pick words with negative connotations (the most frequent words were 'I don't know', bad, fake, scary, science and modified). The word associations for gene editing were similar to word associations for GM. Participants had a low awareness of gene editing (i.e., half had not heard of gene editing).

Carson, S. G. (2019). Labelling of Genome-Edited Food Products - From Consumer Trust to Consumer Responsibility. In E. Vinnari & M. Vinnari (Eds.), *Sustainable Governance and Management of Food Systems: Ethical Perspectives* (pp. 233-238). Wageningen Academic Publishers. https://doi.org/10.3920/978-90-8686-892-6_32.

Study details: Scholarly literature, Conference paper / proceedings, Discussion, Other / General (target). High quality, medium relevance.

Key findings: Analysis of the regulatory system in Norway, particularly around labelling of GM and genome edited food. Argues that food producers should provide labelling and product information about genome edited food (i.e., information which addresses risks and benefits, sustainability and ethics). However, they should not provide too much information which would confuse the consumer. Also argues that consumers should be active rather than passive. In other words, consumers are also responsible for seeking out balanced information.

Clapp, J., & Ruder, S. L. (2020). Precision Technologies for Agriculture: Digital Farming, Gene-Edited Crops, and the Politics of Sustainability. *Global Environmental Politics*, *20*(3), 49-69. https://doi.org/10.1162/glep_a_00566.

Study details: Scholarly literature, Journal article, Discussion, Other / General (target). Medium quality, medium relevance.

Key findings: This article analyses the rise of precision technologies for agriculture—specifically digital farming and plant genome editing—and their implications for the politics of environmental sustainability in the agri-food sector.

The paper maps opposing views in the debate over the environmental aspects of these technologies. Proponents of these technologies claim that they bring environmental benefits in terms of addressing climate change, reducing toxins, and improving resource efficiency in ways that benefit farmers. Critics, on the other hand, argue against these claims, making the case that these technologies require stricter regulatory control because they can result in vexing environmental side effects and further concentrate power in the hands of corporate actors in ways that undermine farmer autonomy. Instead, critics advocate for an entirely different technological system based on agroecological principles, to achieve the goal of sustainable agriculture. The authors argue that key insights from the broader literature on the social effects of technological change—in particular, technological lock-in, the double-edged nature of technology, and uneven power relations—help to explain the political dynamics of this debate.

Coles, D., Frewer, L. J., & Goddard, E. (2015). Ethical Issues and Potential Stakeholder Priorities Associated With the Application of Genomic Technologies Applied to Animal Production Systems. *Journal of Agricultural & Environmental Ethics*, *28*(2), 231-253. https://doi.org/10.1007/s10806-015-9529-z.

Study details: Scholarly literature, Journal article, Empirical, Food animals, Qualitative, Media study. Medium quality, medium relevance.

Key findings: This study uses a literature review to explore the range of ethical issues and potential stakeholder priorities associated with the application of genomic technologies applied to animal production systems. Four ethical principles (autonomy, non-malfeasance, beneficence, and justice) are applied to 7 interest groups (scientists and developers, farmers, food manufacturers and distributors, workers, consumers, animals and the biotic environment), comparing GM and genomic technologies. The authors argue that because genomics avoids many of the disadvantages and consumer perceptions associated with GM, it is likely to prove more publicly acceptable than GM for the development of healthier and more productive animals. However, stake-holders also need to have an approach to the moral status of the animals involved that finds credibility and acceptability with civil society.

Connor, M., & Siegrist, M. (2010). Factors Influencing People's Acceptance of Gene Technology: The Role of Knowledge, Health Expectations, Naturalness, and Social Trust. *Science Communication*, *32*(4), 514-538. https://doi.org/10.1177/1075547009358919.

Study details: Scholarly literature, Journal article, Empirical, Multiple (target), Qualitative, Survey (500-999 participants), Europe. High quality, medium relevance.

Key findings: This paper looks at factors relating to Swiss consumers' acceptance of gene technologies, looking at both agricultural and non-agricultural domains. People's knowledge of biological / genetic concepts much higher than knowledge of the regulations governing them. Medical applications of gene technology were more accepted than non-medical applications. People evaluated the risk of non-medical applications more highly than the risks of medical applications. Furthermore, people perceived more benefits from medical applications than from nonmedical applications. Higher basic biological knowledge is positively related to greater acceptance for both types of applications. Specific knowledge about gene technology does not have an association with the acceptance of either medical or nonmedical applications. Knowledge about legal regulations in Switzerland has a negative correlation with the acceptance of medical applications and no correlation with the acceptance of non-medical applications. Furthermore, health and environmental expectations, risk perception of medical and nonmedical applications, and perceived naturalness are negatively related to the acceptance of both medical and nonmedical applications. The benefit perception of medical and nonmedical applications and social trust are positively associated with people's acceptance of these applications. Age is negatively related to the acceptance of medical gene technology application, whereas it is positively related to the acceptance of nonmedical applications. The paper did not find either a linear or a nonlinear correlation between knowledge and acceptance of gene technology. In conclusion, for either type of application, the paper found that perceived benefits and risks had the highest correlations with the acceptance of gene technology.

Cook, A. J., & Fairweather, J. R. (2003). New Zealand Farmer and Grower Intentions to Use Gene Technology: Results From a Resurvey. *AgBioForum*, *6*(3), 120-127.

Study details: Scholarly literature, Journal article, Empirical, Other / General (target), Qualitative, Survey (100-499 participants), New Zealand. High quality, medium relevance.

Key findings: Survey of New Zealand farmers and growers. Aims to determine whether attitudes and intentions to use gene technology change over time (does this by re-surveying participants from original survey conducted two years earlier). Finds no significant change in attitudes (i.e., intentions to use gene technology/purchase GM food remained generally negative). 41% of participants had negative intentions about gene technology, 34% were neutral and 25% had positive intentions about gene technology. 43% of participants had negative intentions to purchase GM food, 40% were neutral and 17% had positive intentions to purchase GM food. 50% of participants did not agree that New Zealand should become genetic engineering free, 17% were neutral and 33% agreed that New Zealand should become genetic engineering free (this indicated less support for New Zealand becoming genetic engineering free than the previous survey). Participants rated increased food production as the most desirable outcome of gene technology (of the eight outcomes measured including better quality food, new risks to public health, enhanced economic growth, consumer acceptance, adverse effects for future generations, damage to ecological systems and personal risk). The use of gene technology and organic methods was generally considered to be incompatible.

Cook, A. J., & Fairweather, J. R. (2007). Intentions of New Zealanders to Purchase Lamb or Beef Made Using Nanotechnology. *British Food Journal*, *109*(9), 675-688. https://doi.org/10.1108/00070700710780670.

Study details: Scholarly literature, Journal article, Empirical, Food animals, Mixed methods, Survey (500-999 participants), New Zealand. High quality, medium relevance.

Key findings. This paper examines attitudes to the use of a nanoparticle to create a GM animal that allowed the 'genetic material to be rearranged' without the introduction of foreign DNA - so very similar in concept the CRISPR. Willingness to purchase is surprisingly high, but the other attitudinal statements here about concerns for animals etc are really interesting and mirror current MLA work Information was provided to participants. Knowledge etc not tested. There were a range of attitudinal measures examined in this project - several conflicting. 61% said it would feel unnatural to consume, but 76% said they would buy the product. Biggest concerns raised here was lack of compliance with rules or regulations (73%). Most also agreed that animals used to make this product may suffer unforeseen health problems. In addition, nearing one half believed there was a risk that the use of modified animals will result in the contamination of farmland. Risk to the consumer seems not to have been included in the survey. As mentioned, - results are conflicting. 76% said they would purchase, which is much higher for any other GM product in New Zealand as noted by the authors. That said, 49% said they saw themselves as the kind of person who would avoid this product. Researchers examined aspects related to theory of planned behaviour and identity, but found that attitude had the strongest influence on intention (which I note actually runs counter to TPB). The product itself was aimed at health.

Cook, A. J., Kerr, G. N., & Moore, K. (2002). Attitudes and Intentions Toward Purchasing GM Food. *Journal of Economic Psychology*, *23*(5), 557-572. https://doi.org/10.1016/s0167-4870(02)00117-4.

Study details: Scholarly literature, Journal article, Empirical, Other / General (target), Quantitative, Survey (100-499 participants), New Zealand. Medium quality, medium relevance.

Key findings: Older paper on GM that takes a theory of planned behaviour approach, looking at the relationship between attitude and intention (to purchase/consume) rather than attitudes per se. Authors comment their small sample is probably not representative and only 10% had positive intentions. Damage to ecological systems, risks to society, adverse effects for future generations and personal risk were generally considered to be undesirable and likely to occur. Profits for multinational companies were generally considered to be undesirable and were judged to be the most likely consequence of the production of GM food. Enhanced economic growth was generally considered desirable and likely. A reduction in the use of harmful chemicals was desirable, but was judged less likely to occur than the other consequences. Better quality food was desirable, but was generally considered to be an unlikely consequence. This paper looks at the relationship between attitude and intention to purchase GM food in 2002 (little GM food available in New Zealand). The sample size is small and not representative. Some comments in the discussion about tactics for promotion are interesting but not exceptionally relevant to FSANZ report. There are several surveys mentioned that might be of more use. Main useful aspect is the risks that were identified and in particular the aspect of whether people thought it would be likely that a particular consequence would occur.

Cormick, C. (2003). Perceptions of Risk Relating to Biotechnology in Australia. *International Journal of Biotechnology*, *5*(2), 95-104. https://doi.org/10.1504/IJBT.2003.003604

Study details: Scholarly literature, Journal article, Discussion, Multiple (target), Quantitative. Low quality, low relevance.

Key findings: This paper discusses findings from a Biotechnology Australia study in 2001, fully documented elsewhere. Here qualitative comments on attitudes to biotechnology are explored. These include: concerns about biotechnology for corporate profit or career advancement (generally against); concerns about the modification of genetic material in human cells (decline in acceptability, 51% in 1999 to 44% in 2001); concerns about the modification of genetic material in plant cells using animal genetic material (decline, 51% in favour in 1999 to 31% in 2001); concerns about the use of human genes in animals to grow organs (decline in acceptable, 20% in 1999 to see 16% in 2001); making plants more pest resistant more favourable, 20% in 1999 to 37% in 2001. Argues that public confidence depends on information, regulation, consultation, consumer choice and consumer benefit.

Cormick, C. (2004). What Does the Public Really Think About Genetically Modified Food? *Food Australia*, *56*(8), 382-383.

Study details: Scholarly literature, Editorial / Opinion, Australia. Low quality, low relevance.

Key findings: This opinion piece discusses a few aspects of attitudes to GM food in Australia, based on data published elsewhere. Argues there has been a slight rise in acceptance of GM food, between 25% in 1999 and 45% in 2003, though based on different surveys. Argues perceptions of GMO being risky have risen in that two-year period, but concerns have not. I'm not sure how these concepts are delineated, nor what data this is based on. Conjecture that this is associated with September 11. Regardless, risk appears high, between 67 and 74% 1999-2003. Argues that risk and behaviour are decoupled - while risk benefit acceptability showed a drop in support for GM, likelihood a person would eat GM rose. Argues that the biggest factor in consumer rejection of GM is that they see no benefits in GM, as opposed to previously being concerned about health and safety. Evidence for this not cited. Argues that attitudes to GM driven by attitudes toward food and food safety, rather than toward the technology (e.g., a health food buyer will avoid GM, but

someone who doesn't care too much about what they eat will have much less concern about GM). However no evidence was presented for this. Does argue that attitudes depend on the product. Argues community will more likely accept GM if they have proven consumer benefits, regulators had increased profile, and there were less links to multinational food companies.

Cormick, C. (2016). Public Attitudes Toward Biotechnology. In B. Panis, T. A. K. Hvoslef-Eide, R. Drew, & V. Lane (Eds.), *Xxix International Horticultural Congress on Horticulture: Sustaining Lives, Livelihoods and Landscapes* (Vol. 1124, pp. 81-90). https://doi.org/10.17660/ActaHortic.2016.1124.12

Study details: Scholarly literature, Journal article, Empirical, Other / General (target), Qualitative, Survey (1000+ participants), Australia. High quality, medium relevance.

Key findings: Survey of Australian public in order to determine attitudes toward genetically modified foods and crops. Males tended to be more supportive of GM crops than females. Those in a younger age bracket (16-30) were more likely to support GM crops. When asked about which factors would change their negative attitude to a positive one, the most important factors were long-term test of at least 10 years having shown no risks to human health or the environment and labelling of GM food. The most valued benefits associated with GM foods were healthier and cheaper food. Those participants who were least enthusiastic about the benefits of science and technology had the lowest opinion of GM. Conversely, those participants who were the most enthusiastic about the benefits of science and technology were most supportive of GM. 49% of participants believed that the benefits of GM food outweighed the risks, although this rose to 59% if the modification was based on genes from the same species.

Cormick, C., & Mercer, R. (2017). *Community Attitudes to Gene Technology.* Report prepared for the Office of the Gene Technology Regulator. Instinct and Reason.

Study details: Grey literature, Other report, Empirical, Other / General (target), Mixed methods, Survey (1000+ participants), Australia. Medium quality, high relevance.

Key findings: This report continues the series of reports prepared for the OGTR on Australian attitudes to GM food. Knowledge about what foods in Australia were genetically modified is generally poor, and there was little movement in awareness and understanding of GM issues and concerns. There has been a general decrease in awareness of the key terms of biotechnology and GM. Those who have heard of an application but know little about it are still the majority, except for synthetic biology and gene editing which both recorded very high Have NOT heard of it responses. The overall finding of the 2017 survey is that attitudes to GMOs have settled, mirroring very closely the results from the 2015 study, and not showing the degree of change seen between previous studies. This does not mean that attitudes won't change rapidly if they are influenced by some external factors (for example, media coverage), but it does suggest that in the absence of such factors attitude changes will not be major. Those strongly opposed to GMOs are about 13% of the population across different measures, and these respondents stood out as having more extreme attitudes to food and agriculture than any other group, as well as low overall trust. Support for GMOs is more varied and cannot be given just one figure because it is so often conditional, based on regulation and safety being ensured, and the type of modification and its purpose. For example, there are large differences in support for GMOs in medical (63%), industrial (55%), environmental (54%), and food and crops (38%). Those who supported the growing of GM crops in their state or territory and those who were opposed to it were even at 36%, and with 28%unsure. The don't know or unsure ratings were high across most questions. Segmenting the audience into four groups based on their support for GM foods, almost half the respondents were open to the production of GM food as long as regulations were in place to make sure it was safe. About a quarter were against the production of food this way until the science could prove it was safe.

As has repeatedly been shown in previous studies, people have different attitudes toward different forms of genetic modifications, and there is more support for modifications that are perceived to be less radical. A clear majority of respondents felt that biotechnology would improve our way of life in the future (71%), which was up from both 2015 (69%) and 2012 (64%). There was also large support for synthetic biology, with 62% (up from 59% in 2015) stating they felt it would improve our way of life in the future. It is interesting to compare this to awareness of synthetic biology, which was much lower, at only 43%. In addition, more than half of respondents (57%) indicated they thought gene editing would improve our way of life in the future. Belief that GMOs and cloning of animals would improve our way of life in the future, however, remained static at 46% and 32% respectively, following drops from 2012. Just over one quarter of respondents (26%) felt that GMOs would make things worse in the future. The data shows that 13% are completely against gene technology and 10% are completely in favour of it. These figures have not changed much over the years, but represent those who tend to be most active in lobbying for and against gene technologies. When looked at in context of the overall population, just under a quarter of all people have strong views on the subject. While this is still a significant number, it is perhaps less than those at polar opposites are perceived to be.

There was little change in the value placed on the different purposes of GM plants and food. Those objectives that rated most valuable were: drought resistance and healthier food (both 43%); pest-resistance (38%); to make the food cheaper (34%); ability to grow in salty soils and to make the food last longer (both 29%); frost resistance (2); toto make the food taste better (25%); to make plants herbicide tolerant (21%); and to make plants mature more quickly (20%). Data across the age groups (clustered into three age cohorts of 16–30, 31–50 and 51–75) showed a general trend of younger people being more supportive of GM foods of all kinds, and those aged 31–50 being the least supportive.

Looking at the data by gender confirmed the general trend that males were more supportive of GM foods than females, with the exception of meat from animals fed GM stock feed and GM fruits and vegetables, where both had low support. Interestingly, males rated lower on support for GM fruit and vegetables (23% for males and 26% for females) although

the difference was minimal. Using a series of attitudinal statements, respondents were placed in one of four categories related to attitudes to GM food. Half the respondents agreed with the statement that they were open to the production of food this way as long as the regulations were in place to make sure it was safe. Thirteen per cent of respondents accepted that it was a safe way to produce food and 13% were opposed to the production of food this way and nothing was likely to change their mind. The remaining 24% stated that they were against the production of food this way until the science proved it was safe. When the 13% who most opposed to GM foods were measured across other questions asked in the survey, they were shown to have the lowest levels of trust, were very high users of Google for information, and generally had a position on most questions that was quite extreme compared to other groups.

Cormick, C., & Mercer R. (2019). *Community Attitudes Toward Gene Technology*. Report prepared for the Office of the Gene Technology Regulator. Instinct and Reason.

Study details: Grey literature, Other report, Empirical, Quantitative, Survey (1000+ participants), Australia. High quality, high relevance.

Key findings: This report prepared for the OGTR documents Australian attitudes to GM food in 2019. Knowledge about what foods in Australia were genetically modified remains poor. There has been a general continued decrease in awareness of the key terms of biotechnology and GM, and the largest response category to questions about awareness tended to be those who had heard of an application but knew very little about it. As in 2017, the exception was for synthetic biology and gene editing which both recorded very high Have NOT heard of it responses. Understanding of the term biotechnology dropped significantly, from 17% to 12%, with those who had not heard of it rising from 20% to 27%. Also of significance, those who responded that they knew enough about an application to explain it to a friend, dropped over four years quite drastically. For those who knew enough about biotechnology to explain it, the drop was from 19% in 2015, to 17% in 2017 to12% in 2019. Likewise, GMOs and cloning of animals, which had relatively high responses to those who said they knew enough about them to explain to friends in 2015, suffered strong drops. For GMOs the drop was from 33% in 2015 to 30% in 2017 and 22% in2019. The overall finding of the 2019 survey is that attitudes to genetically modified organisms (GMOs) have moved more toward neutral middle positions, as well as an increase in those who aren't sure or don't know, and some reduction in those with stronger views.

Those most strongly opposed to GMOs, however, have stayed constant at about 13% of the population across different measures, and these respondents stood out as having more extreme attitudes to food and agriculture than any other group, as well as low overall trust. We can see a trend emerge whereby the proportion of those who are less supportive of GMOs has declined since 2015, and the proportion of respondents who are neutral has increased significantly. Support for GMOs is more varied and cannot be given just one figure because it is so often conditional, based on regulation and safety being ensured, and the type of modification and its purpose. For example, there is a wide difference in support for GMOs in medical (58%), industrial (53%), and food and crops (35%). The support for growing GM crops overall was similar to previous years, with 36% in favour and 32% opposed, however we have seen a gradual significant increase in the proportion of 'don't know' responses from 26% in2015 to 32% in 2019. Of note, the don't know or unsure ratings were high across almost all questions. There has also been a slow drop in the percentage of respondents who felt that biotechnology would improve our way of life in the future (71% in 2017 to 62% in 2019), but also a slow decrease in those who felt that GMOs would make things worse in the future (29% in 2015 to 26% in 2017 to 24% in 2019. This is getting close to double the amount of people thinking GMOs or GM will improve our way of life in the future as those who feel it will make things worse (45% to 24%).

There was an overall drop in the values that people placed on the different objectives of genetically modifying plants and foods for particular outcomes. Those seen as very valuable were: drought resistance (38%); healthier (38%); pest-resistance (31%); frost resistance (27%); ability to grow in salty soils (24%); to make the food cheaper (32%); to make the food last longer (25%); to make the food taste better (21%); to make the plants herbicide tolerant (20%); and to make the plants mature more quickly (16%). While all of these responses represented a diminution of those who saw the attributes as very valuable, there was not a general corresponding increase in attitudes that these attributes were not valuable. Rather there was a general increase in the Don't Know responses, and a slipping of values from very valuable to somewhat valuable. Data across the age groups (clustered into three age cohorts of 16–30, 31–50 and 51–75) showed a general trend of younger people being more supportive of GM foods of all kinds, and those aged 51–75being the least supportive. Looking at the data by gender confirmed the general trend that males were more supportive of GM foods than females.

Cormick, C., Romanach, L., & Craig, O. (2017). Searching for the Holy Grail: Untangling the Complexity of Public Attitudes Toward Agricultural Biotechnology. *International Journal of Biotechnology*, *14*(3), 210-230. https://doi.org/10.1504/IJBT.2017.084621.

Study details: Scholarly literature, Journal article, Empirical, Other / General (target), Quantitative, Survey (1000+ participants), Australia. Medium quality, medium relevance.

Key findings: This paper documents results of a series of surveys of Australian consumers on attitudes to agricultural biotechnology. Suggests awareness of biotechnology was high, with 80% aware of the term in 2012, 9 out of 10 respondents aware of cloning, 87% aware of applications relating to GM. Awareness of biotechnology applications appears to be increasing over the survey period. Knowledge is lower than awareness - 3 in 5 said that had heard of biotechnology but knew very little or nothing about it. About 23% knew enough to be able to explain it to a friend. Men (30% versus 16%) claimed to know more. Knowledge declined when questions were more specific - 68% had heard of GM introducing genes from a different or same species of plant; 46% aware of modifying plant genes by introducing genes of a bacterium; 25% aware of modifying genes of a plant by introducing the genes of an animal.

People uncertain of the prevalence of GM agriculture - 55% said they did not know whether most of the cotton grown in Australia is GM; 36% did not know whether most of the fruit and vegetables grown in Australia is GM. 29% said (erroneously) that most of the processed foods in Australian supermarkets contain GM. When considering benefits versus risks, people most in favour of cisgenesis (59% benefits outweigh risks, 17% risks outweigh benefits); then genes from a different species [assumed plant here] (38% versus 19%); then bacterium (26% versus 27%), then finally from an animal (12% versus 44%). As the scale tilted toward risks outweighing benefits, 'don't know' increased as well. When considering WTC GM origin food, people are highly diffuse, and not typically polarised. On a 10-point Likert scale 14% were extremely hesitant (0), 15% were in the middle (5) and 5% were extremely willing (10). All other numbers varied between 4% and 12% - with no normal distribution - suggesting no significant clustering or pattern. Participants were asked what would change their minds on GM. Key factors likely to change minds of those not in favour to greater acceptance were "crops provided positive outcomes for the environment or climate change" (63%), "benefits to health" (62%), "passed stringent health and environment regulations" (60%). (Noting here that regulation must not only exist, but be perceived to exist). Other concepts (if farmers "wanted to plant GM crops" (35%), enhance Australia's economic competitiveness (35%)) were outweighed by those saying they wouldn't help the argument. Asked in a different way, health benefits (avg 7.0 on a 10-point Likert scale) the most valued potential benefit of GM, then cost (avg 6.3), then last longer (5.9) and taste better (5.0).

Of those who thought the risks of GM outweighed the benefits, only long-term studies (10 years) would change their minds (56% more accepting, 34% no I wouldn't). Labelling (47% more, 49% no), Australian origin (35% versus 59%), Government certification 32% versus 58%), government development (31% versus 63%), cost (21% versus 74%) all didn't convert many. Some gender differences were found, though not a straight line. Age had some impact, younger respondents more likely to be swayed by labelling, Australian origin, government certification. Someone most likely to be supportive is younger, male, have heard of biotechnology, and science supportive. Someone least likely to be supportive is older, female, not heard of biotechnology, retired, sceptical of science.

Cox, D. N., Evans, G., & Lease, H. J. (2007). Predictors of Australian Consumers' Intentions to Consume Conventional and Novel Sources of Long-Chain Omega-3 Fatty Acids. *Public Health Nutrition*, *11*(1), 8-16. https://doi.org/10.1017/s136898000700016x.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Qualitative, Survey (100-499 participants), Australia. High quality, medium relevance.

Key findings: Analysis based on survey of South Australians. Tested likelihood to purchase foods rich in long-chain omega-3 fatty acids, including farmed fish fed GM oilseed as well as bread, milk and supplements containing GM oilseed. Current practices (i.e., fish fed fishmeal and fish oil supplements) were preferred over novel technologies. Of the two novel technologies, fish fed GM oilseed was more preferable. Half of the participants were given additional information about the benefits of omega-3 fatty acids, the limitations around fish supply and information about alternatives; however, this had no impact on acceptance of novel products. Participants who had arthritis or who's significant other had arthritis were more likely to purchase products containing GM oilseeds.

Cox, D. N., Evans, G., & Lease, H. J. (2008). Australian Consumers' Preferences for Conventional and Novel Sources of Long Chain Omega-3 Fatty Acids: A Conjoint Study. *Food Quality and Preference*, *19*(3), 306-314. https://doi.org/10.1016/j.foodqual.2007.10.006.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Quantitative, Survey (100-499 participants), Australia. Medium quality, medium relevance.

Key findings: This paper reports on a conjoint study of the influence of product (concept) attributes on Australian consumers' preferences for conventional and novel (genetically modified, GM) sources of foods rich in long chain omega-3 fatty acids (LCO3FA). It is apparent that for the majority of the sample (cluster groups 1 and 2), fish fed GM oil was an option that they were positive about and would consider purchasing. The conjoint analysis results indicate that supplements with GM oil would be less favourable than fish but more favourable than bread with added GM oilseed. Recent survey data suggests 48% of Australians would buy GM nutritionally enhanced foods. The sample clustered into three groups: Conservatives" (28%) - significantly less positive about the benefits and safety of the technologies in general, and rated themselves as the least likely of the cluster groups to be vulnerable to heart disease. (Interesting, not sure how the causation works on that). They were less confident that they would consume novel foods containing LCO3FA, although they rated GM oilseed-based products more favourably than cluster group 3. Cluster group 1 can be considered to be generally ''conservative" in attitudes and behaviour. (2) ''Confident protectors" favourable toward GM (51%). Typically, cluster group 2 was positive about the benefits and safety of both technologies used to produce LCO3FA, and believed they were at increased risk of heart disease and that it was important to choose a protective diet. They also rated the 'naturalness' of both fishmeal and GM oilseed sources of LCO3FA more positively. Generally, they were confident that they would consume foods containing LCO3FA, including those foods containingLCO3FA derived from a GM oilseed source. Cluster group 2 can be considered to be ''confident protectors" of their health. (3) ''anti-GM" (20%). Cluster group 3 rated the benefits and safety of both sources of LCO3FA lowest of the 3 groups. However, there was little difference between cluster group 3 and cluster group 2 for the risk of heart disease variables and they rated the severity heart disease higher than participants in cluster group 1. Cluster group 3 can be generally considered to be ''anti-GM".

Clearly, there must be some role for information provision, however it would seem that extensive information has little effect on responses (i.e., support was found for null hypothesis (1), a finding that is consistent with rejection of the knowledge deficit paradigm.

Critchley, C., Nicol, D., Bruce, G., Walshe, J., Treleaven, T., & Tuch, B. (2019). Predicting Public Attitudes Toward Gene Editing of Germlines: The Impact of Moral and Hereditary Concern in Human and Animal Applications. *Frontiers in Genetics*, 9(704), 1-14. https://doi.org/10.3389/fgene.2018.00704.

Study details: Scholarly literature, Journal article, Empirical, Food animals, Quantitative, Survey (1000+ participants), Australia. High quality, high relevance.

Key findings: This paper looks at germline versus other types of gene editing applications in humans and animals used in research and food. The use in food animals was less acceptable than human medical applications but more acceptable than for human enhancement. Knowledge is low. Respondents in CATI and online panel groups averaged 2.8 and 2.91 respectively (where 0= know nothing and 10 = I know a great deal). Level of support for gene editing in food animals (An animal body cell to alter its characteristics for human purposes (e.g., leaner beef in cows) was lower than human medical applications but higher than gene editing for human enhancement Not risk per se but related to risks associated with germline editing. Result that hereditary and moral concern are independent therefore suggests that policy makers and regulators keen to accommodate public opinion should consider carefully the separate issues involved with editing embryonic compared to other types of germ cells. Trust in scientists was relatively high for both groups (CATI:M=3.83, SD=0.99; OLP:M=3.70, SD=1.05) in response to being asked "how much do you trust scientists" (0=Don't trust at all−5=Trust a very great deal).

Dawson, V. (2007). An Exploration of High School (12-17 Year Old) Students' Understandings of, and Attitudes Toward Biotechnology Processes. *Research in Science Education*, *37*(1), 59-73. https://doi.org/10.1007/s11165-006-9016-7.

Study details: Scholarly literature, Journal article, Empirical, Multiple (target), Quantitative, Survey (100-499 participants), Australia. Medium quality, low relevance.

Key findings: Knowledge of GM and other biotechnologies amongst school students is quite low, but does go up with education, though some concepts (cloning) are easier to understand than others (GM). Attitudes to GM amongst Australian school students most favourable ~75% in microorganisms, ~70% in humans (e.g., testing for genetic diseases), ~55% in plants, and least favourable in animals ~30%. Age and education appear to point to greater acceptance. Though the conclusions don't quite say it, there appears only a weak association between acceptance and knowledge.

Dawson, V., & Schibeci, R. (2003). Western Australian School Students' Understanding of Biotechnology. *International Journal of Science Education*, *25*(1), 57-69. https://doi.org/10.1080/09500690210126720.

Study details: Scholarly literature, Journal article, Empirical, Quantitative, Survey (1000+ participants), Australia. Low quality, low relevance.

Key findings: This paper explores to what extent does compulsory school science education prepare Western Australian students for technological citizenship? Are students, as a result of their science education, able to make an informed contribution to public debate about issues such as cloning of human cells to produce a new individual, or the cultivation of genetically modified crops? More specifically, what do students know about biotechnology, genetic engineering, cloning and genetically modified food? Australian students demonstrated a similar knowledge of biotech to other countries (Taiwan, UK). Examples given were of high profile (e.g., cloning) rather than common (yeast) examples. Regarding genetic engineering, the most common example was food / ag, next was cloning. Authors note this indicates a poor understanding of what genetic engineering is. Clearly, this sample of 15-year-old students knows very little about biotechnology. Interestingly, authors report widespread belief amongst students that many foods are GM, though a third couldn't provide an example of an actual GM food. Suggests confusion about what GM is. Suggests that knowledge leads to improved attitudes, but without evidence.

Debucquet, G., Baron, R., & Cardinal, M. (2020). Lay and Scientific Categorizations of New Breeding Techniques: Implications for Food Policy and Genetically Modified Organism Legislation. *Public Understanding of Science*, *29*(5), 524-543. https://doi.org/10.1177/0963662520929668.

Study details: Scholarly literature, Journal article, Empirical, Multiple (target), Qualitative, Focus group (0-99 participants), Europe. high quality, high relevance.

Key findings: This study works on a focus group to compare expert and lay attitudes toward NBTs. In line with the literature, results showed that for non-experts, plants/food produced by NBTs will never be equivalent to plants/food from traditional BTs, and that there is no evidence that developing plants/food with higher "benefits" for consumers would increase their acceptance. Some appreciated the word 'targeted', as opposed to random modifications, though others liked random as it was like nature. It is the 'unknown,' 'inherent risk' of random techniques that is the source of the anxiety. While scientists classify genetic BTs according to the overall mechanism and the genetic tools used to intervene on DNA, non-expert people use more complex heuristics to assess the 'degree' and the 'nature' of human interventions on DNA. Results correspond to these two kinds of attitude: people with Cartesian logic (Cluster 1) had

more confidence in targeted techniques, which they perceived as more controlled, and people with naturalistic logic (Cluster 2) had a more positive perception of random techniques, which they perceived as more in line with natural mechanisms. Cluster 1 judged the relevance of the exogenous gene with the yardstick of gene complementarity. Cluster 2 focused on the taboo of infringement of natural barriers. Moreover, Cluster 1 was composed of more students and younger people of various education and socio-demographic levels, while Cluster 2 was composed of more middle-aged and older people of higher education and socio-demographic levels. The lay classification of NBTs suggests that innovators and legislators should carefully address the underlying questions raised by consumers: 1. Does the technique intervene on the DNA sequence? 2.Does the technique rely on random changes or targeted changes? 3.Does the technique rely on the insertion of exogenous DNA?4. Does the exogenous gene come from distantly or closely related species?

De Marchi, E., Cavaliere, A., Bacenetti, J., Milani, F., Pigliafreddo, S., & Banterle, A. (2019). Can Consumer Food Choices Contribute to Reduce Environmental Impact? The Case of Cisgenic Apples. *Science of the Total Environment*, *681*, 155-162. https://doi.org/10.1016/j.scitotenv.2019.05.119.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Quantitative, Survey (500-999 participants), Europe. Medium quality, high relevance.

Key findings: This paper is a WTP experiment looking at cisgenic apples. Echoing previous literature on GM food, they find in about 37% of the population (the 'attentive' group) significant negative preference toward cisgenic food compared to conventional options. The second most important influence is country of origin, with a local preference appearing. But in 54% ('Technology indifferent'), the technology attribute is the only one that is non-attended to in the choice process, while all the other characteristics of the apple alternatives (namely, Price, COO, and Brand) are weighed by individuals and ultimately contribute to the final choice outcome. This could be due to lack of knowledge of the technology of production. Finally, 9% are technology driven, with the food production technology the key driver of choice, and may refuse to purchase if cisgenic is the only option. Consumers can be segmented, according to this analysis, into attentive, indifferent and technology driven groupings. These groups display quite different attitudes to the technology of apple production, from being indifferent (though potentially this is masked by other considerations, such as COO) to attentive, to driven. "

Dibden, J., Gibbs, D., & Cocklin, C. (2013). Framing GM Crops as a Food Security Solution. *Journal of Rural Studies*, *29*, 59-70. https://doi.org/10.1016/j.jrurstud.2011.11.001.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Qualitative, Other (method), Australia. High quality, low relevance.

Key findings: Provides a comparison of attitudes toward GM crops in the UK and Australia, drawing on documentary evidence (e.g., reports, media, public enquiries). Argues that the issue of global food security is a key component of the GM debate which is used by those both for and against GM.

Edenbrandt, A. K. (2018). Demand for Pesticide-Free, Cisgenic Food? Exploring Differences Between Consumers of Organic and Conventional Food. *British Food Journal*, *120*(7), 1666-1679. https://doi.org/10.1108/bfj-09-2017-0527.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Quantitative, Experiment (500-999 participants), Europe. High quality, high relevance.

Key findings: This paper explores Danish consumer WTP for rye bread produced using conventional, cisgenic and organic methods. Respondents were able to differentiate between transgenics and cisgenics. Traditional breeding (base level) is preferred over both transgenic and cisgenic GM methods, though cisgenic methods are seen less negatively than transgenics. Organic is by far the most preferred production method, although the large standard deviation relative to the mean imply variation between consumers. Consumers did not alter their valuation of the transgenic product (rye bread) when it was pesticide-free, while they valued it positively when achieved by cisgenic methods Domestic bread is favoured over imported. Frequent organic consumers are more sceptical toward transgenics, and don't differentiate between transgenics and cisgenics. However, the conventional and occasional organic consumers do, on average, not differentiate between cisgenics and conventional, although there is large variation within the segments.

Edenbrandt, A. K., Gamborg, C., & Thorsen, B. J. (2017). Consumers' Preferences for Bread: Transgenic, Cisgenic, Organic or Pesticide-free? *Journal of Agricultural Economics*, *69*(1), 121-141. https://doi.org/10.1111/1477-9552.12225.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Quantitative, Survey (500-999 participants), Europe. Medium quality, high relevance.

Key findings: This paper studies consumer preferences for rye bread alternatives based on transgenic or cisgenic rye, grown conventionally or without the use of pesticides, relative to traditionally bred rye, grown with conventional or organic farming methods. Results show that consumers differentiated between transgenics and cisgenics–preferring cisgenics over transgenics–while the traditional breeding method was still preferred by the majority of the respondents, which is consistent with previous studies. Results show that respondents prefer pesticide-free production

methods, and that while cisgenics is preferred over transgenics, the majority of respondents favour traditional breeding methods. Some respondents prefer bread from cisgenic crops produced without pesticides over traditional crops produced using pesticides. A non-trivial group of our respondents did not differentiate between cisgenics and traditional breeding. Consumers place large importance on the domestic aspect, which in the case of bread may be considered as a cue for freshness. Some consumers will be more likely to accept cisgenic crops when pesticide free.

El-Kafafi, S. (2007). Genetic Engineering Perception in New Zealand: Is It the Way of the Future? In A. Ahmed (Ed.), *World Sustainable Development Outlook 2007: Knowledge Management and Sustainable Development in the 21st Century* (pp. 200-209). Greenleaf Publishing Limited. https://doi.org/10.4324/9781351280242-18.

Study details: Scholarly literature, Book chapter, Discussion, Other / General (target). Medium quality, medium relevance

Key findings: Provides an overview of key aspects associated with genetic engineering in New Zealand (e.g., regulation, debates both for and against). Provides historical background on Maori attitudes toward genetic engineering. In 1988, a Maori gathering called for a ban on new organisms over concerns about the impact on species and habitats, the impact on Maori sovereignty over resources and the impact on Maori values. The Maori people also consider GM to go against their rights under the Treaty of Waitangi and believe that they have not been adequately consulted. They are also critical of the lack of benefits they are likely to experience from the technology as opposed to transnational companies and are also critical of the commodification of biodiversity/loss of genetic biodiversity.

Evans, G., & Cox, D. N. (2006). Australian Consumers' Antecedents of Attitudes Toward Foods Produced by Novel Technologies. *British Food Journal*, *108*(10-11), 916-930. https://doi.org/10.1108/00070700610709968.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Quantitative, Survey (100-499 participants), Australia. Medium quality, medium relevance.

Key findings: The purpose of this paper is to identify antecedents of attitudes toward foods produced by novel technologies, including high pressure processing (HPP) (orange juice); GM for a "health benefit" (omega-3 margarine); novel cereals with resistant starch for a "health benefit" where the traits were identified by GM to understand selected gene function prior to utilising traditional breeding techniques to achieve desired novel traits (pasta); and infertility technologies (triploidy and irradiation) for farmed aquaculture (prawns). Plain margarine was rated more favourably than margarine with GM Omega 3 for the sensory, natural, price, familiarity, ecological welfare and impression constructs. Similarly, plain margarine was rated more favourably than margarine with added fish oil for the sensory, price, familiarity and ecological welfare constructs, while margarine with added fish oil was rated more favourably than margarine with GM Omega 3 oil on the natural construct only. The technologies associated with pasta followed a similar pattern to the other technology that contained a product descriptor with the phrase "genetically modified" embedded in the text describing the development of the product, even though the resultant product was described as being produced by traditional breeding methods.

Negative beliefs persisted despite the GM examples being "second generation" GM products with health and consumer benefits or, in another product, when GM was not used in the final "healthy" product. No consistent gender or age effects found. Consumers who consumer a product consistently judge variants more favourably. The strong technology effect found for prawns is consistent with previous findings that, while modification involving plants is sometimes acceptable, the idea of modification of animals is far less acceptable. This notion appears to be supported to some extent by the significantly lower belief evaluation ratings for the natural content, ecological welfare, religious values and political values constructs.

Farid, M., Cao, J., Lim, Y., Arato, T., & Kodama, K. (2020). Exploring Factors Affecting the Acceptance of Genetically Edited Food Among Youth in Japan. *International Journal of Environmental Research and Public Health*, *17*(2935), 1-22. https://doi.org/10.3390/ijerph17082935.

Study details: Scholarly literature, Journal article, Empirical, Multiple (target), Quantitative, (100-499 participants). Low quality, high relevance.

Key findings: This paper explores the factors affecting acceptance of gene edited food among youth in Japan, but is not broadly representative, and is designed in such a way that is not likely to tell us very much. Perhaps the strongest useable result is the indication that increased knowledge (demonstrated by a science communication intervention) increases the adoption of and trust in genetically edited food. Participants went from 24% WTP prior to a science communication intervention, 41% after. Seems to be very much underpinned by a deficit model approach, perhaps colouring many of the findings and interpretations. Also a narrow sample, and time between surveys very small.

Ferrari, L., Baum, C. M., Banterle, A., & De Steur, H. (2021). Attitude and Labelling Preferences Toward Gene-Edited Food: A Consumer Study Amongst Millennials and Generation Z. *British Food Journal*, *123*(3), 1268-1286. https://doi.org/10.1108/BFJ-09-2020-0820.

Study details: Scholarly literature, Journal article, Empirical, Multiple (target), Quantitative, Survey (100-499 participants), Europe. Medium quality, high relevance.

Key findings: This paper surveys Gen Z and Millennials from Belgium and the Netherlands for their attitudes toward gene-edited food. Not a wide sample (young people in Belgium and Netherlands), but overall, the sample was characterized by mid-level scores of subjective knowledge on GM and gene-edited food, but subjective knowledge on GM policy in the EU was significantly lower: confirmed by the objective knowledge scores: on average, participants correctly answered 4.9 out of six questions on general objective GM knowledge versus only 1.27 out of four questions on GM policy. Consumers generally had a positive attitude toward gene-edited food, regardless of generation. Overall, the mean average for pro-statements was significantly higher than that for the anti-statements. Those from the hard sciences were more positive. Attitudes toward gene-edited food were determined by environmental concern (negative) and objective knowledge (positive). Key factors influencing preferences for gene-edited food labelling were a non-hard-scientific background, knowledge about relevant policies and a negative attitude toward gene-edited food. Preference for applying a similar labelling policy to both GM and gene-edited food was itself linked to having low, objective EU policy-related GM food knowledge and one's nationality. Consumers with a hard-scientific or medical background tended to know more about GM and gene-editing techniques and were less concerned about gene-edited food overall. Knowledgeable consumers were more willing to accept gene-edited food. Consumers with more negative perceptions of environmental risk were less willing to accept gene-edited food.

Fleming, J. S. (2004). Ethical, Cultural and Spiritual Objections to Genetically Modified Organisms: A Review of the New Zealand Process and Perspective. *ATLA Alternatives to Laboratory Animals*, *32*(SUPPL. 1A), 21-27.

Study details: Scholarly literature, Journal article, Empirical, Other / General (target), Qualitative, Survey (1000+ participants), New Zealand. Medium quality, medium relevance.

Key findings: Outline of findings from the New Zealand Royal Commission on Genetic Modification. Also provides a breakdown of some of the key themes uncovered during public consultations, including views of Maori participants. As part of the Commission, telephone surveys were conducted. More than 93% of those surveyed were aware of the term GM. 67% of those surveyed were aware that scientists used GM in research using animals (29% approved of this) whilst 72% of those surveyed were aware that scientists used GM in medical research (65% approved of this). During the surveys, less than 3% of participants mentioned GM when asked about which issues they saw as important for New Zealand's future (once the topic was mentioned by the interviewer, more than half of the participants indicated that GM was an important issue for New Zealand's future). 54% of those surveyed approved of the use of GM for pest control, while 70% disapproved of GM use in farm animals. Consultations also revealed that Maori participants were particularly concerned about transgenic animals containing human genes. Of the over 10,000 public submissions received by the Commission, over 92% of these were against GM. Almost 50% of submissions were concerned about environmental risks, 36% were concerned about public health risks, 30% were concerned about food safety risks, 16% were concerned about ethical/spiritual implications, 2.8% were concerned about religious implications, 0.6% were concerned about animal rights and 0.1% were concerned about human rights.

Fortin, D. R., & Renton, M. S. (2003). Consumer Acceptance of Genetically Modified Foods in New Zealand. *British Food Journal*, *105*(1-2), 42-58. https://doi.org/10.1108/00070700310467483.

Study details: Scholarly literature, Journal article, Empirical, Other / General (target), Quantitative, Survey (100-499 participants), New Zealand. Medium quality, medium relevance.

Key findings: The two main objectives of this research were to test whether or not GM affected consumer acceptance of food products measured for both bread and milk) and whether the inclusion of an additional benefit measured by longevity), altered the acceptance levels of GM products. Old GM paper - knowledge not examined, examined through behaviour. The presence of GM had a significantly negative association with consumer attitudes toward the brand. The results show that GM has a negative effect on a consumer's purchase consideration. The additional product benefit, longevity, had no significant effect on consideration of purchase, for bread.

FSANZ. (2003). *Report on the Review of Labelling of Genetically Modified Foods*.

Study details: Grey literature, Government report, Discussion, Other / General (target), Mixed methods. Medium quality, medium relevance.

Key findings: This report presents a review (3 years in) of the November 2000 mandatory labelling requirement for GM foods. The report covers a range of matters, including consumer attitudes in relation to the labelling and acceptance of GM foods. As the report notes, "Attitudes to and acceptance of GM foods is a very complex area. Studies use a variety of indicators to determine the level of consumer acceptance of GM food such as expressed concerns, whether they will eat/buy GM products or whether consumers consider that the perceived risks of GM foods outweigh the benefits. Each of these provides different insights into the acceptance of GM foods such that it is difficult to arrive at a definitive position as to whether consumers, in general, are for or against GM foods". After presenting results of other surveys, the

report then describes a FSANZ survey, in which a total of 1940 people in Australia and New Zealand were interviewed and considered GM food labelling together with other labelling elements, indicates that the use of GM food labelling is not a priority amongst consumers. In the survey Australian and New Zealand participants were asked to identify from 15 examples all the labelling elements they use, even if only occasionally, when purchasing food. Only 16% of respondents said they use GM food labelling which ranked eleventh behind labelling elements such as date marking, ingredients list and Nutrition Information Panels (NIPs).

Submissions point to related evidence. A submission to this review from the Australian Food and Grocery Council stated that member companies have indicated that there is no significant customer demand for increased labelling with respect to GM foods or ingredients. They do note that whilst companies receive customer inquiries with regard to the use of GM foods and ingredients in products, this does not directly relate to requests for increased labelling detail. They also note that any increased customer inquiries correlate more with increased 'anti-GM' publicity. This is also illustrative of the situation in New Zealand. A submission from the New Zealand Grocery Marketers Association stated that member companies received few inquiries about GM foods on their customer service hotlines. Of the thousands of calls that large food manufacturing companies receive annually, approximately 2% or less of the calls relate to GM inquiries. In summary, in Australia and New Zealand the majority of consumers want GM food labelling so that they can choose whether or not they purchase GM foods. There is also support among consumers in Australia for labelling that is process based which would mean labelling of all foods (including ingredients) that are derived from an organism produced using gene technology irrespective of whether novel DNA and/or novel protein is present in the final food. However it is difficult to determine the strength of the link between consumer demand for GM food labelling and actual use of GM food labelling in purchasing behaviour. It appears that consumers want to have the ability to choose whether they eat GM foods, whether they exercise that choice or not.

Gamble, J. C. (2009). Guardians of Our Future: New Zealand Mothers and Sustainable Biotechnology. *Public Understanding of Science*, *18*(2), 189-198. https://doi.org/10.1177/0963662507080349.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Qualitative, Focus group (0-99 participants), New Zealand. Medium quality, medium relevance.

Key findings: New Zealand mothers (aged 20-51) with children (aged 10 and under) took part in focus groups to determine their opinions on four applications of biotechnology: non-transgenic GM plants, bioremediation/bioprospecting, pre-implantation genetic diagnosis and GM pest-resistant trees. Participants indicated that they felt better informed after taking part in the focus group and found the information interesting. Almost three quarters of participants indicated that they followed the biotechnology debate only occasionally or not at all. This indicated a limited involvement in the biotechnology debate. Bioremediation was the most acceptable form of biotechnology of all four applications.

Gatica-Arias, A., Valdez-Melara, M., Arrieta-Espinoza, G., Albertazzi-Castro, F. J., & Madrigal-Pana, J. (2019). Consumer Attitudes Toward Food Crops Developed by CRISPR/Cas9 in Costa Rica. *Plant Cell Tissue and Organ Culture*, *139*(2), 417-427. https://doi.org/10.1007/s11240-019-01647-x.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Quantitative, Survey (1000+ participants), Other location. Medium quality, high relevance.

Key findings: paper surveys adults in Costa Rica for their perceptions and attitudes toward the production and consumption of CRISPR / Cas9 crops. Only 3.7% of the interviewees had heard or read a little (1.9%), some (1.2%), or a lot (0.6%) about the topic. Many agreed that CRISPR foods would increase crop production in the country (66.0%), improve the economy (63.7%), and bring benefits to their families (60.7%) and the environment (57.4%). Nearly half of the interviewees perceived low or no risk to the quality of life, health, and environment. A higher percentage would consume CRISPR foods if the nutritional quality were better (70.8%), if they were cheaper than conventional products (61.0%), and if they were available in the national market (59.4%). Approximately half of the interviewees would be willing to purchase a kilo of rice or beans (traditional Costa Rican food products) if they were priced the same as conventional products. In general, a high percentage of Costa Rican consumers would accept the use of gene editing for nature conservation (84.5%), curing diseases in animals (83.0%), crop improvement (80.9%) and curing human diseases (80.2%).

Gjerris, M., Gamborg, C., & Rocklinsberg, H. (2018). Could Crispy Crickets Be CRISPR-Cas9 Crickets - Ethical Aspects of Using New Breeding Technologies in Intensive Insect-Production. In S. Springer & H. Grimm (Eds.), *Professionals in Food Chains* (pp. 424-429). Wageningen Academic Publishers. https://doi.org/10.3920/978-90-8686-869-8_67.

Study details: Scholarly literature, Conference paper / proceedings, Discussion, Other / General (target). High quality, low relevance.

Key findings: Raises some ethical questions about the potential use of CRISPR in insect production. Points out that the use of biotechnology in insect breeding could make it more difficult for people to relate to insects.

Hanson, D., & Tranter, B. (2006). Who Are the Shareholders in Australia and What Are Their Ethical Opinions? An Empirical Analysis. *Corporate Governance-an International Review*, *14*(1), 23-32. https://doi.org/10.1111/j.1467-8683.2006.00481.x.

Study details: Scholarly literature, Journal article, Empirical, Other / General (target), Quantitative, Survey (1000+ participants), Australia. Medium quality, medium relevance.

Key findings: Seeks to understand the impact of ethical considerations on Australian shareholders (i.e., scenarios in which shareholders would sell their shares). Ethical scenarios which were tested include whether the company caused a major environmental problem, used child labour, produced military weapons, gave large bonuses to executives, invested in GM crops/food and had been prosecuted for racial discrimination. Found that participants were more likely to sell their shares than keep them if the company invested in GM crops/food. Of the six scenarios, GM was ranked 3rd highest for likelihood to sell (when combining probably sell and definitely sell categories). Also contains statistics relating to impact of gender, age, education, income and political orientation on attitudes toward GM crops/food (e.g., men were more likely to keep their shares than women; those on the right were more likely to keep their shares than those on the left).

Helliwell, R., Hartley, S., & Pearce, W. (2019). NGO Perspectives on the Social and Ethical Dimensions of Plant Genome-Editing. *Agriculture and Human Values*, *36*(4), 779-791. https://doi.org/10.1007/s10460-019-09956-9.

Study details: Scholarly literature, Journal article, Empirical, Other / General (target), Qualitative, Media study (0-99 participants), UK, Medium quality, medium relevance.

Key findings: This paper examines environmental, food and farming NGOs' social and ethical concerns about genome editing, situating these concerns in comparison to alternative ethical assessments provided by the Nuffield Council on Bioethics. It doesn't cover consumer attitudes directly, but does find NGOs mostly show considerable overlap in concerns with the Nuffield council, but the NGOs seek to challenge the existing order and broaden the scope of debate to include deeply political questions regarding agricultural and technological choices. The participant NGOs consistently sought to challenge the status quo, attempting to expand the boundaries of discussion to include explicit questions about power and its dynamics, particularly with regard to the perceived increase in corporate influence within agricultural systems from the adoption of genome editing techniques. Consequently, NGO participants framed their engagement through 'who' and 'why' questions, drawing attention to who is instigating these debates and with what intentions.",

Henderson, A., Weaver, C. K., & Cheney, G. (2007). Talking 'Facts': Identity and Rationality in Industry Perspectives on Genetic Modification. *Discourse Studies*, *9*(1), 9-41. https://doi.org/10.1177/1461445607072105.

Study details: Scholarly literature, Journal article, Empirical, Multiple (target), Qualitative, Media study, New Zealand. Medium quality, low relevance.

Key findings: This article explores the rhetorical and discursive construction of public messages about GM by two major New Zealand export industries. The kiwifruit industry advocates a very cautious public policy position, while the dairy industry has been a strong advocate for the commercial development of GM.

However, these industries draw on multiple identities and rationalities to express and explain these negotiated public policy positions informed variously by discourses of risk, science, the political economy of the marketplace, and images of the 'natural' environment.

In the kiwifruit industry, GM policy is described as largely market-driven because it is determined by the preferences of customers and consumers, and the industry's major international markets, Europe and Japan, are referred to as GM risk-averse, such that consumers will not purchase GM. Appears that other arguments (e.g., clean, green) are used in service of this dominant rationale.

The dairy industry positioning on GM, like that of the kiwifruit industry expressed and explained as being driven by the market. However, while the kiwifruit industry is primarily concerned about the values and attitudes of customers in Europe and Japan who are GM risk-averse, such concerns are not foregrounded in dairy industry documents. The dairy industry, like ZESPRI, justifies its position on GM by arguing that the industry success is important to New Zealand, because of New Zealand's economic dependence on primary industries. However, the future economic success of the dairy industry is then articulated with remaining competitive as indicated in Fonterra's media statement on 14 September 2001: The reality every New Zealander should understand is that our economy is overwhelmingly dependent on biological products, including dairy products, meat, wool, fish, and fruit and vegetables. Maintaining and enhancing New Zealanders' living standards depends on the country maintaining and enhancing competitiveness of these key industries. (Fonterra, 14 September 2001) The prioritization of 'living standards' as evidence of success and well-being, rather than, for example, care for the environment or educational standards and knowledge acquisition, highlights the economic perspective that is privileged in the dairy industry GM position,

Henderson, J., Ward, P., Coveney, J., & Meyer, S. (2012). Trust in the Australian Food Supply: Innocent Until Proven Guilty. *Health Risk & Society*, *14*(3), 257-272. https://doi.org/10.1080/13698575.2012.662948.

Study details: Scholarly literature, Journal article, Empirical, Other / General (target), Qualitative, Interviews (0-99 participants), Australia, High quality, low relevance.

Key findings: Interesting findings in general about trust in food supply/regulation in Australia. However, the article only briefly mentions GM. Rural and farming participants were generally critical of GM crops.

Ipsos-Eureka. (2010). *Community Attitudes to Biotechnology 2010: Conducted for the Department of Innovation, Industry, Science and Research.* Ipsos-Eureka Social Research Institute.

Study details: Grey literature, Other report, Empirical, Other / General (target), Mixed methods, Survey (1000+ participants), Australia. Medium quality, medium relevance.

Key findings: This report presents results of a community survey on attitudes to biotechnology in Australia. Of the terms 'IVF', 'Stem cell research', 'Genetic modification' and 'Biotechnology', biotechnology least well understood. (Or, more precisely, perceived understanding). Higher awareness / perceived understanding amongst Males, metro, uni education, technophiles. Awareness of use of GM in food production remains high overall, yet much lower regarding specific applications. Knowledge: No significant changes in knowledge since 2007. Majority know most fruit and veg grown in Aus in not GM. Fewer than one in four know most processed foods in Australia are GM-free. Perceived future negative impact highest in GM (30% believe GM will make things worse). Perceived negative impact higher amongst women, regional, vegan, lower education, technophobes. Greater support for health and medical applications of GM than food and agriculture; decline in acceptance of both 2007 to 2010. Regarding potential benefits of GM, the majority perceive some value in each of the benefits presented (drought resistance, salt tolerance, health benefits, pest resistance, frost resistance). Drought (63% very valuable, 25% somewhat valuable 2010) and salinity resistance (50% very, 31% somewhat) and healthier (54% very, 26% somewhat) food were perceived as the most valuable objectives of GM food crops. Least valued were to make food taste better." Increase in perceptions of risk associated with GM 2007 (31%) to 2010 (39%). Low stated willingness to eat all food types other than organic food, including foods commonly eaten. Willingness lowest for cloned, followed by GM, meat products. Notably, people less willing to eat food containing preservatives than GM foods. Perceived utility of application declines as the relationship between the plant and secondary organism becomes more distant; same-species GM seen as much less risky than inter-species GM. Perceptions of risk increase when additional details are given (data doesn't quite support this). Strongest mitigators of anti-GM food crop sentiment are long-term tests and labelling describing what and why.

Ishii, T., & Araki, M. (2016). Consumer Acceptance of Food Crops Developed by Genome Editing. *Plant Cell Reports*, *35*(7), 1507-1518. https://doi.org/10.1007/s00299-016-1974-2.

Study details: Scholarly literature, Journal article, Discussion, Food plants. High quality, low relevance.

Key findings: Discussion paper which provides suggestions of ways to improve consumer acceptance of genome edited food. Argues that governments should facilitate communication between developers and the public. Argues that developers should create cultivars which will be viewed favourably by consumers. Also argues that developers should initially avoid multiplex genome editing in agricultural contexts to make it easier to facilitate risk-benefit communication. Argues that developers should fully inform the public about the advantages and disadvantages of plant breeding techniques (this should be based on the consumer's viewpoint).

Jaeger, S. R., & Harker, F. R. (2005). Consumer Evaluation of Novel Kiwifruit: Willingness-to-Pay. *Journal of the Science of Food and Agriculture*, *85*(15), 2519-2526. https://doi.org/10.1002/jsfa.2330.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Quantitative, Experiment (0-99 participants), New Zealand. Medium quality, low relevance.

Key findings: This paper introduces a research methodology to measure consumer WTP. In experimental markets, New Zealand consumers were willing to pay on average approximately NZ$0.44 per 100g to exchange the common, green-fleshed Hayward variety for a new-to-market red- and yellow-fleshed kiwifruit variety. At the time of the study this was equivalent to a 179% retail price premium. Knowledge that this new variety was not genetically modified increased the price premium to 240%. This does suggest that novelty can, in and of itself, offer a premium. However, GM clearly a potential detractor.

James, S., & Burton, M. (2003). Consumer Preferences for GM Food and Other Attributes of the Food System. *Australian Journal of Agricultural and Resource Economics*, *47*(4), 501-518. https://doi.org/10.1111/j.1467-8489.2003.t01-1-00225.x.

Study details: Scholarly literature, Journal article, Empirical, Multiple (target), Quantitative, Survey (100-499 participants), Australia. Medium quality, medium relevance.

Key findings: This paper reports choice modelling methods to examine the conditions under which Australian consumers are willing to purchase GM foods, if at all, and examines those preferences within the context of the food system as a whole. Consumers require a discount on their weekly food bill before they will purchase GM food. Gene technology using animal as well as plant genes was found to be more objectionable to respondents than that using plant genes alone, especially among women. A woman aged 35 years would pay a premium of approximately 8 per cent to avoid a basket with 30 per cent GM foods, compared to an 18.2 per cent premium to void a basket with 100 per cent GM foods. Males seem to be less concerned with gene technology in food in general, and not at all significantly concerned about gene technology involving plants alone. A respondent being male will modify (i.e., soften) the negative response to GM foods by 0.273 (plants only) and 0.661 (plants and animals). While this indicates a less adverse stance than for females, the modifiers are not large enough to out-weigh the GM partworth and hence the partworths for males are still negative overall. Age seems to affect the preferences for a certain type of food, with older people generally more accepting of the use of gene technology.

Kassardjian, E., Gamble, J., Gunson, A., & Jaeger, S. R. (2005). A New Approach to Elicit Consumers' Willingness to Purchase Genetically Modified Apples. *British Food Journal*, *107*(8), 541-555. https://doi.org/10.1108/00070700510610968.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Mixed methods, Experiment (0-99 participants), New Zealand. Medium quality, medium relevance.

Key findings: A majority of participants in this study were ready to pay for the GM apples. No clear difference found in WTP when comparing GM apples beneficial for either environment or health, though participants wrote significantly more positive thoughts about environmentally beneficial apples than health beneficial. Participants spontaneously noted they were interested in trying the GM apples, some suggesting their WTP was about this factor. Curiosity could be used to attract consumers in the first place. Suggests a difference between survey and experimental results, perhaps also a difference between stated attitudes and actual behaviours. Curiosity can be used to attract people. Opinion and WTP are linked.

Kato-Nitta, N., Maeda, T., Inagaki, Y., & Tachikawa, M. (2019). Expert and Public Perceptions of Gene-Edited Crops: Attitude Changes in Relation to Scientific Knowledge. *Palgrave Communications*, *5*(137), 1-14. https://doi.org/10.1057/s41599-019-0328-4.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Quantitative, Survey (1000+ participants), Other location. Medium quality, high relevance.

Key findings: This study empirically examined expert and public attitudes to gene editing, GM or conventional breeding of agricultural crops. Lay public tended to have more favourable attitudes toward gene editing than toward GM, such differences were much smaller than the differences between conventional breeding and GM. Molecular biology experts had higher benefit and value perceptions, experts in other fields showed some characteristics that are similar to the experts in molecular biology in value perceptions. Molecular biology experts had lower risk perceptions regarding new technologies (gene editing and GM). Experts in other fields showed risk perceptions similar to the lay public. Risk typically slightly lower for gene editing than GM. Statistical analyses of lay attitudes revealed the influence of science literacy on attitudinal change toward crops grown with new breeding technologies in benefit perceptions but not in risk or value perceptions.

Kaye-Blake, W., Bicknell, K., & Saunders, C. (2005). Process Versus Product: Which Determines Consumer Demand for Genetically Modified Apples? *Australian Journal of Agricultural and Resource Economics*, *49*(4), 413-427. https://doi.org/10.1111/j.1467-8489.2005.00311.x.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Quantitative, Interviews (100-499 participants), New Zealand. Medium quality, low relevance.

Key findings: Interviewed New Zealand shoppers split on the risks of GM - 41.1% agree or strongly agree that producing GM food is too risky to be acceptable for me; 25.5% neutral; 33.4% disagree or strongly disagree. The research reported in this paper addresses whether consumers consider the specific attributes of genetically modified food (GMF) products, or instead react generally to the process of GM (GM) in food. The results support both sides of the argument. A sizeable minority (33.3%) does not react categorically to GM as a food attribute. For them, the value of GM apples is determined by the specific benefits that can be provided. The value that they attach to the attribute GM is a function of the specific benefits that GMF offers. Here respondents prefer apples with greater flavour and have negative WTP for GM apples, but are willing to set aside some of their aversion to GM apples when presented with apples with better flavour or less insecticide. On the other hand, a large minority (41.1%) might not consume GMF even if it were free: the total discount demanded exceeded the original cost of the conventional apples. For these respondents, the process of GM in food production is decisive in their assessments of the apples offered. The choices of the remaining consumers (25.5% of the sample) would be affected by the estimated attribute interactions, but the base GM discount is also relatively sizeable; the net impact on their choices is difficult to categorise.

Kaye-Blake, W., O'Connell, A., & Lamb, C. (2007). Potential Market Segments for Genetically Modified Food: Results From Cluster Analysis. *Agribusiness*, *23*(4), 567-582. https://doi.org/10.1002/agr.20134.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Quantitative, Survey (100-499 participants), New Zealand. Medium quality, low relevance.

Key findings: This paper presents data from a survey of supermarket shoppers in New Zealand analysed with a cluster analysis to show purchasing intentions regarding GM apples. A six-cluster solution found three clusters with positive intentions to purchase three with negative intentions. Clusters positive to purchasing GM were Price Sensitive (15.3%, the only cluster that chose lowest priced apples), True Believing (13%, GM fits their cultural beliefs, believed GM would solve world food problems and did not believe it posed risks, did not believe GM was tampering with nature) and Appreciative (23.3%, like True Believers, but more neutral; disagreed with the statement that 'natural environments have a right to exist for their own sake). Negative clusters were Middle of the Road (18.3%, average on most things but just negative on GM), Opposed to GMF (16.3%, diametrically opposed to True Believers, GM contradicts worldview - not a solution to world food problem, too risky, went against beliefs, ecocentric), Concerned about GMF (13.7%, like Opposed, but not as strident). No significant differences between clusters found for gender, ethnicity, education, presence of children, or main food shopper. Significant differences were organically grown food (though this is not independent), age and income.

Differences in the age distributions across the six clusters were significant but difficult to characterise. The Middle-of-the-Road cluster, which was not inclined to purchase GMF, had the highest average age. On the other hand, the cluster of True Believers and the Appreciative cluster had the next two highest mean ages. The youngest group, on average, was the Concerned cluster, which contained the highest proportion of respondents in their twenties. However, the Opposed cluster had a flatter age profile and was close to the sample mean. From these results, it would seem that the age distributions of the clusters were different but not in a binary way that could be used to predict willingness to purchase GMF. Income also tricky to use. True Believers and Appreciative had highest incomes, but the other positive group (Price Sensitive) had lowest incomes.

Kelley J. (1995). *Public Perceptions of Genetic Engineering: Australia, 1994*. Report to the Department of Industry, Science and Technology. Melbourne Institute of Applied Economic and Social Research.

Study details: Grey literature, Other report, Empirical, Other / General (target), Quantitative, Survey (1000+ participants), Australia. Medium quality, low relevance.

Key findings: This report presents survey data on Australian perceptions of genetic engineering. Overall, a clear majority said they had heard of genetic engineering (68%) and a majority claimed a 'basic understanding' of it (63%). About half were interested in it. Australians are very strongly in favour of scientific research in medicine. They are also very strongly in favour of some agricultural goals (crops that would create an export market, healthier food) and of environmental protection. They are strongly -- but not as strongly -- in favour of scientific research that would increase farmers' incomes, provide cheaper food, or provide tastier food. The Australian public is broadly supportive of a wide range of genetic engineering projects. The average Australian rates the average genetic engineering project as a ''good idea''. Of the genetic engineering products asked about in the survey, the most popular were a treatment for blood cancer, a drug that lowers blood pressure, and cotton that resists insect pests. More than 90% of Australians favoured these. Then comes healthier cooking oil, genetically modified viruses to protect farm crops by attacking insect pests, viruses to control imported animal pests, and lean pork. Support is lowest for the genetically engineered tomato but even here a clear majority is in favour, 64% declaring them to be a "good idea" or a "very good idea" so long as they are clearly labelled. Opposition to genetic engineering is concentrated among people who put a low priority on improvements in health and agriculture as goals for Australian scientists, concentrated among supporters of the Greens, and concentrated among people who dissent from the scientific world-view.

The public wants genetically engineered food products to be clearly labelled, so they can choose for themselves whether or not to use them. Even if genetically engineered foods are in fact entirely safe -- a scientific issue not to be settled by public opinion polling -- people nonetheless want to make the choice themselves. A clear majority of the Australian public think the benefits of genetic engineering will outweigh the risks. Most of the rest have mixed feelings and fewer than 10% think the risks will outweigh the benefits. People who think the benefits will outweigh the risks tend to be those who: - favour the goals, especially agricultural benefits; - are less worried than the average about potential costs; - do not particularly fear fluoridation; - are relatively knowledgeable about genetic engineering; and have a scientific worldview. Conversely, those who think the risks will outweigh the benefits -- the minority -- tend to be those who: - are less keen on agricultural goals than most Australians; - are more worried than the average about potential risks; - fear fluoridation; - know little about genetic engineering; and - reject Darwin's theory of evolution and modern astronomy. These results suggest that the Australian public will increasingly perceive genetic engineering's benefits as outweighing its risks in the future as levels of knowledge increase.

Kilders, V., & Caputo, V. (2021). Is Animal Welfare Promoting Hornless Cattle? Assessing Consumer's Valuation for Milk From Gene-Edited Cows Under Different Information Regimes. *Journal of Agricultural Economics*, 1-25. https://doi.org/10.1111/1477-9552.12421.

Study details: Scholarly literature, Journal article, Empirical, Food animals, Quantitative, Survey (1000+ participants), US. High quality, high relevance.

Key findings: This study uses data from a survey of 1,000 US consumers to determine: (i) consumer WTP for milk from cows that have been gene-edited to be hornless; and (ii) consumers' response to information about how the gene-editing technology works, how it differs from GM, and its benefits for animal welfare. This paper suggests that consumers are not typically aware of conventional dehorning practices. Respondent's WTP increases with more information. Information on animal welfare has the strongest effect on consumer WTP for milk produced from conventionally and genetically dehorned cow. However, as more information is provided, an increasingly wider spread of WTP estimates can be observed in the population, which suggests a polarisation of preferences. Information actively affects the distribution of preferences, but different consumer segments show different sensitivities to the information given.

Knight, J. G. (2016). GM Crops and Damage to Country Image: Much Ado About Nothing? In B. Panis, T. A. K. Hvoslef-Eide, R. Drew, & V. Lane (Eds.), *XXIX International Horticultural Congress on Horticulture: Sustaining Lives, Livelihoods and Landscapes* (Vol. 1124, pp. 23-31). https://doi.org/10.17660/ActaHortic.2016.1124.4.

Study details: Scholarly literature, Conference paper / proceedings, Empirical, Other / General (target), Quantitative, Survey (500-999 participants), New Zealand. Medium quality, low relevance.

Key findings: This paper presents what appears to be the same data as Knight and Clark 2014. It tests the extent to which GMO release in New Zealand would affect the countries 'clean green' image in the eyes of a variety of key international stakeholders, here looking at tourists. Results suggest they would be very unlikely to be influenced by this.

Knight, J. G., & Clark, A. (2014). Biotechnology in the Fruit Industry: Great Science, But What About Our 'Clean Green' Image? In S. E. Gardiner (Ed.), *II International Symposium on Biotechnology of Fruit Species* (Vol. 1048, pp. 207-214).

Study details: Scholarly literature, Conference paper / proceedings, Empirical, Other / General (target), Quantitative, Survey (500-999 participants), New Zealand. Medium quality, low relevance.

Key findings: This paper presents a one component of a wider study (other studies use face-to-face interviews with food industry stakeholders in Europe, China, and India; choice modelling surveys with consumers in Europe and New Zealand; surveys of tourist visitors to New Zealand) to assess the extent to which GMO food would harm New Zealand's 'clean green' image. This paper deals in particular with the evidence of surveys of tourist visitors to New Zealand. Results suggest it is highly unlikely that the introduction of GM plants into New Zealand would have any long-term deleterious effect on perceptions in overseas markets, particularly in Europe.

Knight, J. G., Clark, A., & Mather, D. W. (2013). Potential Damage of GM Crops to the Country Image of The Producing Country. *GM crops & food*, *4*(3), 151-157. https://doi.org/10.4161/gmcr.26321.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Qualitative, Survey (500-999 participants), New Zealand. Medium quality, medium relevance.

Key findings: Seeks to determine whether the introduction of GM plants into New Zealand would have an effect on tourism and food exports. Surveys first time visitors to New Zealand. Medium usefulness as article gathers data on visitors rather than New Zealand citizens. Argues that the introduction of GM plants into New Zealand is unlikely to have a negative impact on tourism or food exports (the evidence used in the paper does not support the argument about food exports; however, the article does point to previous research in this area). Participants were asked about their views on various applications of GM technology. In the case of disease resistant GM pines grown in , New Zealand 92.8% of participants indicated that they would still visit New Zealand. In the case of GM rye grass grown in New Zealand, 92.9% indicated that they would still visit. In the case of GM rye grass grown for animal welfare, 91.4% indicated that they would still visit. In the case of GM bacterium used to clean up DDT, 90.3% indicated that they would still visit. In the case of GM bacteria used to reduce methane, 89.4% indicated that they would still visit. In contrast, when asked about their views on the use of GM technology for food production/environmental protection more generally, 50.8% believed that this type of technology was unacceptable. This suggests that visitors would still choose to visit New Zealand even if they held negative views about GM technology.

Knight, J. G., Mather, D. W., Holdsworth, D. K., & Ermen, D. F. (2007). Acceptance of GM Food - An Experiment in Six Countries. *Nature Biotechnology*, *25*(5), 507-508. https://doi.org/10.1038/nbt0507-507.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Quantitative, Experiment (1000+ participants), New Zealand. High quality, medium relevance.

Key findings: Paper compares consumer WTP in 6 countries (NZ, Sweden, France, Belgium, UK and Germany) for Organic, Conventional and Spray Free GM fruit. All preferred organic (~50% of market), but New Zealand was the most likely to purchase GM fruit at equivalent prices (27%, others ~20%). Modelling suggests New Zealand consumers would be the most likely to purchase GM fruit following pricing differentials (raised price for organic, discount for GM). Findings are in line with the proposition of classical economic theory that consumers will seek to maximize utility. They

are also consistent with data from the latest Eurobarometer report. Although "strong opposition" to the overall concept of GM foods technology was reported, when Eurobarometer respondents were asked whether they would buy GM food "if it contained less pesticide residues than other food," 18% indicated "yes, definitely" and 33% indicated "yes, probably." When asked whether they would buy GM food "if it were cheaper than other foods," 12% indicated "yes, definitely" and 24% indicated "yes, probably".

Lamberts, R. (2017). *The Australian Beliefs and Attitudes Toward Science Survey*. Australian National Centre for the Public Awareness of Science.

Study details: Grey literature, Other report, Empirical, Other / General (target), Quantitative, Survey (1000+ participants), Australia. Medium quality, medium relevance.

Key findings: This report documents a survey exploring Australian attitudes to science, and key scientific issues. Findings include that Australian confidence in GM foods is not uniform. Australians are noticeably happier about eating GM foods than foods grown with pesticides, which is interesting given how common the use of pesticides is in comparison to the relatively low presence of GMOs on Australian supermarket shelves. Nearly half of the Australian respondents (46.6%) believed it is generally safe to eat GM foods, compared to 37% of Americans. A sizable minority of Australians (39.6%) feel GM foods are generally unsafe, a number that rises to 57% in the US. 62.3% of Australians consider pesticides generally unsafe. The more people feel informed, the more positive they are in general. People who felt at least 'fairly well' informed about science were more likely to say that eating GM foods was 'generally safe' (X2=24.610, df=2, sig=.000, Cramer's V=.149, sig=.000). When it comes to eating food grown with GM, men were more likely to see this as 'generally safe' than women (X2=58.814 df=2, sig=.000, Cramer's V=.230, sig=.000). People who had conversations about science on 'at least most days' or more were more likely to say that eating GM foods was 'generally safe' (X2=24.610, df=2, sig=.000, Cramer's V=.149, sig=.000). Respondents whose most recent conversation about science was 'generally positive' were more likely to say that eating GM foods was 'generally safe' (X2=12.261, df=2, sig=.016, Cramer's V=.081, sig=.016. The most highly educated respondents were a little more likely to feel that eating GM foods was 'generally safe' (X2=11.490, df=4, sig=.022, Cramer's V=.072, sig=.022).

Lassoued, R., Macall, D. M., Smyth, S. J., Phillips, P. W. B., & Hesseln, H. (2020). How Should We Regulate Products of New Breeding Techniques? Opinion of Surveyed Experts in Plant Biotechnology. *Biotechnology Reports*, *26*, 1-10. https://doi.org/10.1016/j.btre.2020.e00460.

Study details: Scholarly literature, Journal article, Empirical, Other / General (target), Qualitative, Survey (100-499 participants), Other location. Medium quality, medium relevance.

Key findings: This paper polls international experts in plant biotechnology on what approach should nations agree upon to accommodate current and future new breeding technologies and derived products. Experts most often considered public attitudes (and what they called public confusion) about food safety and health risks the dominant factor related to the use of NBTs to develop new crops (38%). Next were regulatory approval (34%), market access / trade rules (32%), Cost of international biosafety compliance (29%), and confidence in the science of modern genome-specific technologies (21%) and cost to develop a new variety (21%). A key finding is product-based models (59%) or dual-product / process systems (26%) are viewed as potential appropriate frameworks to regulate outcomes of genome editing. Factors that can improve transparency around biotech regulation: 1) Efforts of regulators to communicate / report on own activities; 2) Academic involvement; 3) Farmer involvement; 4) Public engagement / consumer consultation; 5) Voluntary corporate commitment.

Lassoued, R., Phillips, P. W. B., Smyth, S. J., & Hesseln, H. (2019). Estimating the Cost of Regulating Genome Edited Crops: Expert Judgment and Overconfidence. *GM Crops & Food-Biotechnology in Agriculture and the Food Chain*, *10*(1), 44-62. https://doi.org/10.1080/21645698.2019.1612689.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Quantitative, Survey (0-99 participants), Other location. Medium quality, low relevance.

Key findings: This paper analyses survey results used to collect experts' opinions of the likely cost to bring genome edited crops to market. Paper finds that the expected costs of genome edited crops are case specific and depend on whether crops will likely be regulated as genetically modified or accepted as conventional varieties and not subject to any regulatory oversight by federal regulators. In general, experts expected regulated crops to cost 2.5 times as much (US$24.5m versus US$10.5m), and take 2.8 times as long.

Lea, E. (2005). Beliefs About Genetically Modified Foods: A Qualitative and Quantitative Exploration. *Ecology of Food and Nutrition*, *44*(6), 437-454. https://doi.org/10.1080/03670240500348789.

Study details: Scholarly literature, Journal article, Empirical, Other / General (target), Mixed methods, Survey (100-499 participants), Australia. Medium quality, medium relevance.

Key findings: This study is aimed to examine consumers' beliefs about genetically modified foods. Ten focus group interviews of community members and a random questionnaire-based mail survey of 500 Australian (Victorian) adults were conducted. Participants were generally negative about genetically modified foods. 91% said all GM foods should

be labelled; 61% didn't know whether the food they bought was GM or not; 53% that multinational companies take the profits of GM foods, while consumers take the risks. Concerns raised about GM include them being unnatural, difficult to identify, and having unknown long-term health and environmental effects. Many participants were unaware of or disagreed with the benefits of genetically modified foods that are promoted by its advocates and there were some misconceptions present. Some positive comments about GM foods made by some focus group participants, such as GM being another step in the advancement of agriculture. Women in particular were found to be wary or unsure of GM foods. This study suggests consumers need more information about GM foods, such as additional labelling (e.g., providing reasons for why it has been modified). They need to know how to identify food that has been genetically modified from that which is not, as there is clearly some confusion about this. For example, the misconception from the focus group research that fruit that is larger than or otherwise different in appearance to the usual is (necessarily) genetically modified needs to be overcome.

Lockie, S. (2006). Capturing the Sustainability Agenda: Organic Foods and Media Discourses on Food Scares, Environment, Genetic Engineering, and Health. *Agriculture and Human Values*, *23*(3), 313-323. https://doi.org/10.1007/s10460-006-9007-3.

Study details: Scholarly literature, Journal article, Empirical, Other / General (target), Qualitative, Media study, Australia. Medium quality, low relevance.

Key findings: This paper undertakes a content analysis of newspaper articles from Australia, the UK, and the US concerned with a variety of issues relevant to sustainable food and agriculture from 1996 to 2002, looking in particular ash the ways sustainability, organic food and agriculture, genetic engineering, genetically modified foods, and food safety are framed both in their own terms and in relation to each other. A big jump in articles 1999 / 2000 from the years before. The paper finds that media discourses tend to reduce this complexity of sustainability to a straightforward conflict between organic and conventional foods. Despite regular reporting of viewpoints highly critical of organic food and agriculture, this binary opposition frames organic foods as more-or-less synonymous with safety, naturalness and nutrition, and their alternatives - including GM, anything 'agro-industrial' - as artificial, threatening, and untrustworthy. Particularly controversial food-related issues such as genetic engineering, food scares, chemical residues, and regulatory failure are treated as part of the same problem to which organic food offers a trustworthy and easily understood solution. Importantly however, the paper finds no compelling evidence that media reporting of food-borne hazards has been the primary agent responsible for either the level of concern over genetic engineering or the growth of interest inorganic foods. Here very little correlation can be seen even within the media between reporting of food scares and reporting of organics and genetic engineering. The point here is not that the threat of food-borne hazards is irrelevant but that a simple linear relationship between microbiologically-based food scares, declining faith in food regulatory agencies, uncertainty over the long-term implications of the new biotechnologies, and rapid growth in the market for certified organic food is unlikely.

Lockie, S., Lawrence, G., Lyons, K., & Grice, J. (2005). Factors Underlying Support or Opposition to Biotechnology Among Australian Food Consumers and Implications for Retailer-Led Food Regulation. *Food Policy*, *30*(4), 399-418. https://doi.org/10.1016/j.foodpol.2005.06.001.

Study details: Scholarly literature, Journal article, Empirical, Other / General (target), Quantitative, Survey (1000+ participants), Australia. Medium quality, low relevance.

Key findings: In keeping with previous studies of consumer attitudes to biotechnology, this Australian study showed consumers to have mixed, but on average, less positive attitudes toward biotechnologies. High agreement that GM food should be labelled. Agreement (but not strong agreement) that releasing GM organisms into the environment is too risky. This paper presents a path analysis of attitudinal, motivational, demographic and behavioural variables that influence consumer dispositions toward biotechnology. Of the strongest variables, consumers motivated to find foods they considered natural were least favourable toward biotechnology (-.48), and those consumers interested more in convenience were most favourable (.44). Sex had a moderate direct effect with women less likely to be positively disposed toward bio-technology than men (-.22). In an apparent contradiction, taking responsibility for household shopping had an equally strong positive effect on both naturalness and convenience. However, sex also played a crucial role here with a very strong effect on motivation to find natural foods (women more motivated), a minor effect on convenience (women less motivated) and a strong effect on responsibility for household shopping (women more likely to shop).

Lucht, J. M. (2015). Public Acceptance of Plant Biotechnology and GM Crops. *Viruses-Basel*, *7*(8), 4254-4281. https://doi.org/10.3390/v7082819.

Study details: Scholarly literature, Journal article, Discussion, Food plants. High quality, medium relevance.

Key findings: Provides an overview of attitudes toward GM in Europe. Provides evidence from Eurobarometer survey in 2010 which showed that consumers were more supportive of cisgenic apples than transgenic apples. However, most respondents considered cisgenic apples to be unnatural. More than three quarters of respondents also wanted the cisgenic apples to be labelled as GM food. Anti-GE NGOs such as Greenpeace and Friends of the Earth Europe have also called for the precautionary principle to be applied to new breeding techniques and also believe that foods made from NBTs should be labelled as genetically modified.

Maaß, O., Consmuller, N., & Kehlenbeck, H. (2019). Socioeconomic Impact of Genome Editing on Agricultural Value Chains: The Case of Fungal-Resistant and Coeliac-Safe Wheat. *Sustainability*, *11*(6421), 1-26. https://doi.org/10.3390/su11226421.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Qualitative, Interviews (0-99 participants), Europe. High quality, medium relevance.

Key findings: This qualitative study uses semi-structured interviews with key stakeholders to analyse how genome-edited crops could affect agriculture value chains, looking in particular at wheat in Germany. Results show that the use of fungal-resistant and coeliac-safe wheat can provide benefits at each step of the value chains. Fungal-resistant wheat benefits actors by reducing the problems and costs resulting from fungal-diseases and mycotoxins. Coeliac-safe wheat benefits actors by producing high value-added products, which can be safely consumed by patients suffering from coeliac disease. However, the results also show that low acceptance of genome editing by society and food retailers poses a significant barrier for the use of genome-edited crops in agricultural value chains. Several requirements have to be satisfied in order to use fungal-resistant wheat as input for food production. First, the quality parameters (e.g., protein content) and processing characteristics of wheat must not deteriorate due to genome editing. Second, fungal-resistant wheat must fit into the existing processing steps of food production readily. Third, genome editing should have a positive connotation in society and should not be linked to GMO.

Macpherson, T., Kearns, Z., Hedderley, D., & Sharland, S. (2001). Evaluating the Behavioural Impact of the Australian and New Zealand Genetically Modified Food Labelling Provisions. *Journal of Food Products Marketing*, *7*(4), 77-90. https://doi.org/10.1300/J038v07n04_06.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Quantitative, Survey (100-499 participants), Australia. Medium quality, low relevance.

Key findings: This paper presents the results of a choice experiment that encompassed the labelling options outlined in the Australian and New Zealand government's recently finalized mandatory labelling system for genetically modified foods (GMF's) and foods that contain genetically modified ingredients. Results indicate that product labelled as "GM-free" will achieve substantially higher levels of relative utility than other labels tested. This greater utility was consistent for both food products (tomatoes and bread) with this label maintaining a higher utility than "Contains GM" labelled food, even with a 32% difference in price (that is, no other label achieves a greater utility than GM-free at the high price). This indicates that manufacturers and growers of GM-free food will realize a distinct advantage over product utilizing the other GM status labels–particularly "Contains GM" labelled goods. Furthermore, this advantage could be available to manufacturers with GM-free products if they label their product before the regulations take effect, assuming the difference in relative utility between "GM-free" and "No label" holds when these are the only options available. Alternatively, the findings reveal a distinct market disadvantage to GM manufacturers or growers when they are forced by regulations to label their product as such–given an ample supply of GM-free alternatives.

Malyska, A., Bolla, R., & Twardowski, T. (2016). The Role of Public Opinion in Shaping Trajectories of Agricultural Biotechnology. *Trends in Biotechnology*, *34*(7), 530-534. https://doi.org/10.1016/j.tibtech.2016.03.005.

Study details: Scholarly literature, Journal article, Discussion, Other / General (target). Medium quality, medium relevance.

Key findings: Article which calls for greater communication from scientists in order to shape public opinion around NBTs. Argues that, in order to ensure public acceptance of NBTs, scientists need to engage with the debate and provide information to the public. This needs to occur before public opinion becomes firmly set against NBTs. Argues that communication with the public needs to be built into all stages of the research process. Information should be balanced between the risks and benefits and should inform the public of biosafety measures. Scientists should also tailor their information about NBTs toward particular applications which contain benefits viewed favourably by the public. Communicating with the public should also be built into conditions for funding.

Marette, S., Disdier, A. C., & Beghin, J. C. (2021). A Comparison of EU and US Consumers' Willingness to Pay for Gene-edited Food: Evidence from Apples. *Appetite*, *159*, 1-11. https://doi.org/10.1016/j.appet.2020.105064.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Quantitative, Survey (100-499 participants), Europe. Medium quality, high relevance.

Key findings: This paper compared WTP for GM and gene-edited apples in US and France. They found that gene-editing would be treated like GM, but that the discount was steeper for GM (i.e., gene-editing slightly more accepted). US consumers discounted both less than French consumers. The message effects in this paper are interesting for comms researchers but may be of less interest to FSANZ. French consumers preferred longer messages (this part of the study is not as strong as other parts of the paper - and unfortunately the authors take that into recommendations for labelling). In an exit survey, participants were asked about awareness. 66.9% of US compared to 46.3% on France but unclear whether that refers to NBTs or includes GM as experiment included it and the paper says "food innovations and biotechnologies. In sum, US consumers value the improved attributes of the apples as long as the innovation is not based on biotechnology tools (GMO or gene-editing). French consumers do not value the novel apple in any

circumstances. Didn't seem to look at this per se, information about gene-edited- or GMO-apples reduced WTP, but gene-editing information had a smaller negative impact than GMO information The length and type of the message (although this is a bit tricky to decipher). In short, gene-editing was discounted less than GMO but more than the conventional varieties in both countries, but the effect is stronger in France than in the US. And a qualified 'yes' to the question of whether gene-editing would be treated like GM. Also has ambivalent information about labelling.

Marques, M. D., Critchley, C. R., & Walshe, J. (2015). Attitudes to Genetically Modified Food Over Time: How Trust in Organizations and the Media Cycle Predict Support. *Public Understanding of Science*, *24*(5), 601-618. https://doi.org/10.1177/0963662514542372.

Study details: Scholarly literature, Journal article, Empirical, Multiple, Qualitative, Interviews (1000+ participants), Australia. High quality, medium relevance.

Key findings: Seeks to gauge public opinion toward GM plants and animals which are used for food over an extended period of time (interviews were conducted between 2004 and 2012). Authors are also interested in how trust in organisations and media coverage influences public opinion. Article contains a comprehensive overview of literature to date on trust and attitudes toward GM. Participants were more positive about GM plants for food than animals, although levels of support were still relatively low. Positive attitudes toward GM plants and animals were also lower during times of high media coverage about GM food. Trust in watchdogs, regulators and scientists were all predictors of attitudes toward GM, with trust in scientists being the strongest predictor of positive attitudes. There was a correlation between higher trust in scientists/regulators and positive attitudes toward GM plants and animals. There was also a correlation between increased trust in watchdogs and decreased attitudes toward GM. Similarly, there was a correlation between increased trust in environmental groups and negative attitudes toward GM.

Marques, M. D., Kerr, J. R., Williams, M. N., Ling, M., & McLennan, J. (2021). Associations Between Conspiracism and the Rejection of Scientific Innovations. *Public Understanding of Science*. https://doi.org/10.1177/09636625211007013.

Study details: Scholarly literature, Journal article, Empirical, Other / General (target), Quantitative, Survey (1000+ participants), Australia. Medium quality, medium relevance.

Key findings: This paper explores associations between conspiracism (the general tendency to engage in explanations about the cause, or concealment, of threats to human well begin stemming from a secretive network of (purported) malevolent actors) and anti-science attitudes, of which one is opposition to GM food. Suggests broad public opposition to GM food. Anti-science attitudes toward GMO animals and plants for food were moderately associated with increased Malevolent Global Conspiracy. Increased importance in Religion/Spirituality was uniquely associated with increased GMO anti-science attitudes in both samples. GMO rejection for Australians, but not New Zealanders, was associated with increased beliefs in a group of 'puppeteers' manipulating world events and the suppression of information by organizations, consistent with narratives involving the takeover of the agriculture industry by biotech corporations. Remarkably, New Zealand GMO animal rejection was associated with decreased belief in Extra-terrestrial coverups.

Mather, D., Knight, J., & Holdsworth, D. (2005). Pricing Differentials for Organic, Ordinary and Genetically Modified Food. *Journal of Product and Brand Management*, *14*(6), 387-392. https://doi.org/10.1108/10610420510624549.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Quantitative, Experiment (100-499 participants), New Zealand. Medium quality, medium relevance.

Key findings: Study designed to test consumers' willingness to buy GM food compared with organic and ordinary food. Cherries were tested in this case, with the GM version being spray-free (i.e., a scenario in which cherries were genetically modified to make their own natural insecticide). Findings show that there was resistance to the GM product despite it having the benefit of being spray-free. However, the GM product becomes more appealing when given a more competitive price. For example, when all three products were allocated average market prices, 46% of participants chose organic, 27% chose ordinary and 27% chose GM. In comparison, when the organic product had a 15% price premium and the GM product had a 15% price discount (average price for the ordinary product), 20% of participants chose the organic and ordinary products whilst 60% chose GM.

McDougall, D. J., Longnecker, N. E., Marsh, S. P., & Smith, F. P. (2001). Attitudes of Pulse Farmers in Western Australia Toward Genetically Modified Organisms in Agriculture. *Australasian Biotechnology*, *11*(3), 36-39.

Study details: Scholarly literature, Journal article, Empirical, Other / General (target), Qualitative, Survey (100-499 participants), Australia. Medium quality, medium relevance.

Key findings: Explores Western Australian pulse farmers' perceptions of GM. 93% of participants had previously heard about genetic engineering whilst 72% had a basic understanding of genetic engineering. 87% of participants received information about genetic engineering from rural magazines, 78% from radio/television, 64% from public press, 30% from research publications, 26% from public forums and 3% for the internet and other sources. 82% of participants indicated that they were interested in genetic engineering. Participants were asked to rate the acceptability of a range of genetically modified products (these were the same as the Norton et al. 1998 paper). Those products which

contained cross-species/cross-kingdom GM involving animals or humans were considered to be less acceptable. Participants ranked a range of GM-related issues in the following order (from most to least concern): chemical companies, imports refused, herbicide resistant weeds, pest resistance, funding requirements, health crisis, long-term danger to health, plant/wildlife, labelling/acceptance and change to farming systems. Found that those participants who displayed high levels of acceptance could still have high (or low) levels of concern about genetic engineering. 57% of participants indicated that their views on genetic engineering had not changed in the past five years. There was a generally high willingness to use/consume genetically modified organisms among participants (paper provides a breakdown of willingness to use/consume GM lupin, clover seed and wheat). Participants believed that labelling should be present regardless of whether genetically modified material remains in the final product.

McFadden, B. R., & Smyth, S. J. (2019). Perceptions of Genetically Engineered Technology in Developed Areas. *Trends in Biotechnology*, *37*(5), 447-451. https://doi.org/10.1016/j.tibtech.2018.10.006.

Study details: Scholarly literature, Conference paper / proceedings, Review, Multiple (target). Medium quality, medium relevance.

Key findings: This paper reviews literature on perceptions and knowledge of genetic engineering technology in developed areas. Canadians have some awareness about plant varieties and hybrids, with half claiming they are familiar with GMOs. However, considerably less is known about biotechnology. Technologies like mutagenesis that have been used for decades have scant public awareness. Approximately half of Americans displayed some uncertainty about how many genes were altered through various breeding techniques, answering 'I don't know'. However, compared with other breeding techniques, selection was believed to alter no genes, and GM was believed to alter more genes than genetic marker-assisted breeding, mutagenesis, and selection. This may indicate that the term 'genetic modification' implies the alteration of genes while the names of other breeding techniques do not. If so, this finding has implications for the nomenclature used to describe future technologies. Taken together, these results indicate that familiarity with and beliefs about the number of genes altered are dependent on breeding technique. There is marginal awareness of new plant breeding technologies developed and used over the past 20–30 years. The dominant lack of understanding about plant breeding indicates that communicating scientific facts to the public about agriculture is a less-than-optimal strategy and a preferred option would be to communicate stories of the benefits.

In the EU, 82% of consumers had heard of genetically engineered food in 2010, but it is likely that awareness has increased since then. It should not come as a surprise to anyone in agriculture, or agricultural regulation sectors, that there is virtually no awareness of modern techniques like cisgenesis and intragenesis. Perceived knowledge is relatively high, but not affirmed by actual knowledge - perceived familiarity with or knowledge of genetically engineered crops may really just be a proxy for exposure to the terms genetically engineered, GM, or GMO. Basic agricultural concepts such as seed sterility, the need to purchase new seed each planting season, and that new plant varieties are commercially released every year have virtually no public recognition or understanding. While consumer benefits have been and are being quantified, this has not translated into increased levels of consumer support. More than half (55%) of EU consumers support cisgenic application to reduce pesticide residue, compared with 33% support for a transgenic application. On average, Europeans hold more negative perspectives on genetically engineered foods than their American or Canadian counterparts. Consumers perceive that most equity from modern plant breeding is distributed to the private sector, which may stoke concerns about fairness and ownership of the food supply by multinational corporations Canadians exhibit high levels of uncertainty about potential consequences, benefits, and risks of modern plant breeding. In one study, the none-response rate ('neither agree nor disagree' and 'don't know') reached over 50% for some potential genetically engineered crop benefits.

Half of Canadians believe that modern plant breeding benefits only large, multinational corporations and does not benefit small-scale farmers, believing that farmers in developing countries have no option and that new crop varieties are forced on farmers. Americans perceive that seed and chemical suppliers received the largest share of the benefits regarding the distribution of equity for current genetically engineered crops.

Despite mounting literature quantifying the economic, environmental, and human health benefits of their production, one criticism frequently levelled against genetically engineered crops is the lack of consumer benefits, which has resulted in some consumers rejecting this technology. Too often the discussion around biotechnology is posed as a false dichotomy, where consumers either accept or reject the technology. However, it is quite possible for consumers to be more accepting of particular uses of biotechnology. Americans have not found consumer benefits (e.g., nutritional content) or producer benefits (save farmers time) overly desirable. The one exception to this is to help ensure that the USA remains food secure by high levels of domestic crop production. It is clear that affordability and food security are important to consumers. Canadian consumers believe that modern plant breeding makes food more afford-able; similarly, Americans view low food prices as an important aspect of future crop innovation. Framing environmental options negatively, in that more problems would arise, does result in a higher positive response. Has good links on knowledge. Calls for consistent communication messages, but doesn't deal with the fact that that isn't necessarily possible.

McFadden, B. R., Rumble, J. N., Stofer, K. A., Folta K. M., Turner S., & Pollack, A. (2021). Gene Editing Isn't Just About Food: Comments From U.S. Focus Groups. *GM Crops & Food*, 1-11. https://doi.org/10.1080/21645698.2021.1919485.

Study details: Scholarly literature, Journal article, Empirical, Other / General (target), Qualitative, Focus group (0-99 participants), US. High quality, medium relevance.

Key findings: This paper compares public perceptions of gene editing in the US within medical and agricultural contexts. Among other limiting factors, participants were recruited if they had a neutral or positive trust in science. Participants primarily associated gene editing with medical applications as opposed to agriculture/food. Themes discussed in the agriculture/food domain included: food, GMOs, seeds, cloning, Monsanto, farm raised fish and agriculture. Focus group conversations were analysed to determine whether themes were associated with positive, negative or neutral sentiments. All of the agriculture/food-related themes had primarily negative and/or neutral associations (food and seeds were the only two themes which had some positive associations).

Meyer, S. B., Mamerow, L., Henderson, J., Taylor, A. W., Coveney, J., & Ward, P. R. (2014). The Importance of Food Issues in Society: Results From a National Survey in Australia. *Nutrition & Dietetics*, *71*(2), 108-116. https://doi.org/10.1111/1747-0080.12076.

Study details: Scholarly literature, Journal article, Empirical, Other / General (target), Qualitative, Interviews (1000+ participants), Australia. High quality, medium relevance.

Key findings: Seeks to understand Australian consumers' opinions regarding food issues. Also considers the impact of demographic and socioeconomic factors. Participants were asked to rate the importance of four food issues, including additives, GM foods, unhealthy eating and food allergies. Argues that social context is an important factor in determining opinions on food issues. 67.7% of participants considered GM foods to be an important issue (ranked last of the four scenarios). Females were more likely than males to consider GM food an important issue. Those in the 30-59 age bracket were also more likely to consider GM food to be an important issue. There was a correlation between higher levels of education and decreased likelihood to consider GM as an important issue (participants with a degree or higher were 30% less likely to rate GM as important whilst those with a trade/certificate/diploma were 40% less likely - these percentages are in comparison to those participants with education no higher than secondary level). Those participants in the highest socioeconomic bracket were half as likely to view GM food as important compared to those in the lowest socioeconomic bracket.

Mielby, H., Sandoe, P., & Lassen, J. (2012). The Role of Scientific Knowledge in Shaping Public Attitudes to GM Technologies. *Public Understanding of Science*, *22*(2), 155-168. https://doi.org/10.1177/0963662511430577.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Quantitative, Survey (1000+ participants), Europe. Medium quality, medium relevance.

Key findings: This paper explores the role of knowledge in attitudes to various food editing technologies, using a Danish sample. People much happier (55.7% support, versus 18.9%) with cisgenesis compared with transgenesis. Knowledge (as assessed by a series of high school biology questions) increases the likelihood that a person will have differentiated opinions on medical and agricultural applications, but decreases the likelihood that he or she will differentiate between cisgenic and transgenic cereals. Knowledge makes people more likely to base their acceptance on judgements of risks and benefits, rather than on judgements of naturalness. The effect of knowledge on acceptance cannot be generalised wholesale from one application, or method, to others.

Mielby, H., Sandoe, P., & Lassen, J. (2013). Multiple Aspects of Unnaturalness: Are Cisgenic Crops Perceived as Being More Natural and More Acceptable Than Transgenic Crops? *Agriculture and Human Values*, *30*(3), 471-480. https://doi.org/10.1007/s10460-013-9430-1.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Qualitative, Focus group (0-99 participants), Europe. Medium quality, medium relevance.

Key findings: This paper draws on 5 Danish focus groups to examine public perceptions of 'cisgenic crops' and asks whether the public shares the idea that they are less unnatural and thus more acceptable than transgenic plants. In all of the focus groups participants recognized the differences in transformation methods, and would discuss these differences in terms of some methods being more natural than others. They verbalized their concerns about gene technology being unnatural through five distinct lines of argument that referred respectively to: the manner in which GM crops come into being (that they were, in origin, dependent on human interference), the presence of foreign genetic material (unnaturalness results from the inclusion of 'foreign' materials or 'substance', namely genes originating from species other than the recipient's own), the introduction of atypical traits (e.g., taste or physical properties), likely environmental impacts (the anxiety that the release of unnatural crops into the environment could potentially upset the delicate balance of nature), and whether or not the crops were regarded as familiar. Depending on perceptions of naturalness, some people would agree that cisgenic crops are more acceptable than their transgenic counterparts. Particularly those subscribing to a substance view of naturalness.

Mireaux, M., Cox, D. N., Cotton, A., & Evans, G. (2007). An Adaptation of Repertory Grid Methodology to Evaluate Australian Consumers' Perceptions of Food Products Produced by Novel Technologies. *Food Quality and Preference*, *18*(6), 834-848. https://doi.org/10.1016/j.foodqual.2007.01.012.

Study details: Scholarly literature, Journal article, Empirical, Multiple (target), Qualitative, Focus group (0-99 participants), Australia. Low quality, low relevance.

Key findings: Paper explores attitudes (and WTP) for a variety of food technologies across a few food categories (orange juice, margarine, prawns, beef). Both GM categories were the least preferred. Comparison of GM plants (margarine) and animals (beef) suggests no significant difference. During the discussions, two different points of view merged with some participants favourable toward animal modification because it included less risk of crossbreeding and environment pollution, others considered it to be worse than plant modification because of the animal welfare and the health effects of growth hormone. Some mention of risk perceptions with GM. Comparison of GM plants (margarine) and animals (beef) suggests no significant difference. During the discussions, two different points of view merged with some participants favourable toward animal modification because it included less risk of crossbreeding and environment pollution, others considered it to be worse than plant modification because of the animal welfare and the health effects of growth hormone. Lowest likelihood to purchase GM foods, compared with conventional or other food technologies. Paper provides some comparison between different food technologies in four different foods (orange juice, margarine, prawns and beef), with GM foods seeing least preference / likelihood to purchase. However, it is difficult to generalise from there, as all explanations appear particular to the particular food. Weak suggestion of no difference in attitudes to GM animals and GM plants.

Mohr, P., & Golley, S. (2016). Responses to GM Food Content in Context With Food Integrity Issues: Results From Australian Population Surveys. *New Biotechnology*, *33*(1), 91-98. https://doi.org/10.1016/j.nbt.2015.08.005.

Study details: Scholarly literature, Journal article, Empirical, Quantitative, Survey (500-999 participants), Australia. High quality, medium relevance.

Key findings: Paper explores responses to GM food content in context with food integrity issues. Examined GM didn't look at knowledge. Paper makes the case that attitudes to GM are not a special case but are a subset of attitudes to food integrity issues. Sensitivity of environmental and health matters predicts attitudes. Where GM differs from other food integrity issues is the role for intuitive thinking. Almost two-thirds of participants (63.6%) rated their concern about 'use of genetic engineering' in relation to food at 5 or above on a 7-point scale. (Similar to food additives, preservatives and pesticides This paper is basically saying that GM is a particular but not 'special' food integrity issue, and that concern for health and environment are predictors. Main contribution of this paper is that GM is put into a broader food integrity context, although clearly it is from a science/tech position. Paper published in 2016 uses data from 2008 and 2010.

Mohr, P., Harrison, A., Wilson, C., Baghurst, K. I., & Syrette, J. (2007). Attitudes, Values, and Socio-demographic Characteristics That Predict Acceptance of Genetic Engineering and Applications of New Technology in Australia. *Biotechnology Journal*, *2*(9), 1169-1178. https://doi.org/10.1002/biot.200700105.

Study details: Scholarly literature, Journal article, Empirical, Other / General (target), Quantitative, Survey (500-999 participants), Australia. High quality, medium relevance.

Key findings: If only more attention was paid to this paper at the time! Key findings summarised "The simplest conclusion to be drawn from the present findings is that in-principle acceptance of or resistance to genetically engineered food is more parsimoniously explained in terms of general receptiveness toward science and technology than in terms of educational or informational deficiencies, issues of trust, or identification with environmental concerns or movements." As for as NBTs and FSANZ go, I think these are important variables to consider in terms of attitudes and values to NBTs, although it would be important to re-examine whether these have changed in last 15 years, esp when general trust appears to be a lot lower. Even though it's old I think this is useful as there isn't a lot of Australian data like this.

Muggleston, S. (1998). Talking about gene technology: A New Zealand perspective. *Australasian Biotechnology*, *8*(3), 160-163.

Study details: Scholarly literature, Journal article, Editorial / Opinion, Other / General (target). Low quality, low relevance.

Key findings: Provides a description of the services undertaken by Gene Pool, which was an organisation that disseminated information about gene technology to the public in New Zealand. Argues that there needs to be greater two-way communication with the public and more factual discussion in lay terms around gene technology. References Eurobarometer survey in 1997 which found that New Zealand respondents rated biotechnology as a highly important issue. New Zealanders tended to be more appreciative of applications of biotechnology than other parts of the world. 2 out of 3 respondents supported genetic engineering of crops for pest resistance whilst a little over half supported the

use of biotechnology in food and drink. New Zealand respondents were also more knowledgeable about biotechnology than respondents from other parts of the world. Most respondents trusted universities/research institutes to tell the truth about biotechnology. Respondents most often received information about biotechnology from television and newspapers. 1 in 4 respondents believed that current regulations are protecting people from risks. Regulation by international organisations or by scientific organisations/ethics committees was preferred over government regulation.

Muringai, V., Fan, X., & Goddard, E. (2020). Canadian Consumer Acceptance of Gene-Edited Versus Genetically Modified Potatoes: A Choice Experiment Approach. *Canadian Journal of Agricultural Economics*, *68*(1), 47-63. https://doi.org/10.1111/cjag.12221.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Quantitative, Experiment (1000+ participants), Other location. High quality, high relevance.

Key findings: On average respondents prefer frozen French fries with beneficial traits (reduced acrylamide level, reduced food waste, and reduced on-farm pesticide application in potatoes), produced by conventional breeding technology as opposed to GM and gene editing technologies, developed by the government over Monsanto. Older respondents are generally less likely to prefer the attributes as compared to younger respondents. Male respondents are generally more accepting of the GM and gene editing technologies. Consumer WTP for GM transgenic technology is the most discounted among the three genetic technologies we examined. Similar to previous research, we find that GM cisgenic/intragenic technology is preferred to GM transgenic technology. More importantly, our results provide evidence that the WTP discount for products produced with the gene editing technology is less than the discount for the GM cisgenic/intragenic technology. In other words, consumers are more accepting of gene editing technology than GM cisgenic/intragenic technology. WTP rises more with health benefits (acrylamide reduction, pesticide reduction) than environmental benefits (waste reduction). All GM and Gene edited potatoes see price discount (~ -$2/kg) in WTP, no significant difference. Developer does split, from government (+$1/kg) through JR Simple ($0/kg) to Monsanto (~$-1/kg). Fairness relates to interest in GM and Gene editing technologies, results show that government is the most preferred developer of the potatoes, regardless of technology.

Myskja, B. K., & Myhr, A. I. (2020). Non-Safety Assessments of Genome-Edited Organisms: Should They Be Included in Regulation? *Science and Engineering Ethics*, *26*(5), 2601-2627. https://doi.org/10.1007/s11948-020-00222-4.

Study details: Scholarly literature, Journal article, Discussion, Other / General (target). Medium quality, medium relevance.

Key findings: This article presents and evaluates arguments supporting that an approval procedure for genome-edited organisms for food or feed should include a broad assessment of societal, ethical and environmental concerns; so-called non-safety assessment. The article argues that even in situations where genome-edited organisms can be considered comparable to non-modified organisms in terms of risk, the technology may have—in addition to social benefits—negative impacts that warrant assessments. The main arguments for including non-safety assessments in the regulation of genome-edited products are: First, the ownership issue remains the same as with GMOs: this is a patentable technology, although it is yet not clear how that right is affected if the resulting organism also could have been produced by non-patentable methods. Second, genome-editing technologies have, independent of whether there is or is no addition of foreign material, the potential for altering characteristics with significant impact on sustainability, societal issues and ethics. Such non-safety assessments should be considered in any regulatory regime. "

National Gene Technology Scheme (2018). *The Third Review of the National Gene Technology Scheme: Final Report*.

Study details: Grey literature, Government report, Empirical, Other / General (target), Mixed methods, Survey (1000+ participants), Australia. Medium quality, medium relevance

Key findings: This review documents the achievements to 2018 against policy objectives of the National Gene Technology Scheme. The review acknowledges that "it became apparent early on in consultations that the complexity and scope of the Scheme mean that it is not always well understood by all sectors. However, the majority of stakeholders agreed that the Scheme effectively provides for, and should continue to provide for, the health and safety of people and the protection of the environment, from the risks posed by or as a result of gene technology."

Review themes and recommendations of relevance here included: Recognition that while the Scheme is providing a solid regulatory framework, it might be struggling to keep pace with technology; Despite much discussion, stakeholders generally agreed that maintaining the current 'regulatory trigger' [the 'process-based trigger'] would be the most sensible outcome at this point. This position recognises that other regulatory schemes (i.e., food, medicines, etc.) would also need to be reviewed and amended for any change to be effective; Recommendations to ensure the scheme is equipped to regulate work with GMOs undertaken outside of universities, research institutes or large companies.

The Review's discussion on social and ethical issues explored public attitudes and understanding of GM, and the impacts for Australia. Consultation was supported by market research, which identified a number of misperceptions and knowledge gaps. The research found that familiarity with the concept of GM, or 'genetically modified' (GM) varied considerably. Some 60% of those surveyed claimed to be familiar with the term, with 6% believing they know a lot about GM. Over 35% stated that while unfamiliar with the term they had heard of it before. Awareness of GM was primarily limited to crop applications. GM medication and other industrial applications were less well known.

Respondents also raised concerns around the safety of GM, indicating their belief that effects have not been observed and tested over the long term. Some did not know whether: •the food was safe to eat or if medicines were safe; •GM products are adequately tested before being licensed for sale in Australia; or •there is sufficient regulation of GM products in Australia.

When testing attitudes toward GM, the research indicates that respondents were more likely than not to acknowledge that there is a place for GM in today's world. However, respondents commonly mentioned that GM isn't something they typically think about. Further, they are not prompted to think about GM when they go shopping because GM labels aren't something they typically see, so it is not top of mind. 61% agree GM is the way of the future, 27% disagreed.

These highlighted the need for better communication with the public (including the most appropriate body, or bodies, to undertake such communication activities). Increased understanding of the regulatory process and what is and isn't covered by it, is particularly needed, as is better information on risk assessment and the existing transparency measures for communicating regulatory data. To further build public understanding and confidence in the Scheme, the Review recommends the development of additional targeted communication mechanisms. Recommendations also address ongoing concerns within some sectors of the community about the safety of GMOs, and the ability of the Regulator to monitor commercialised GMOs for long-term impacts. Nearly half (47%) of Australians consider that organisations that create GMOs put profit before safety, with only one in five (22%) disagreeing on this issue.

Nature. (2021). Revamp of UK CRISPR Regulation Will Require Public Trust. *Nature*, *591*(7850), 345. https://doi.org/10.1038/d41586-021-00672-1.

Study details: Scholarly literature, Journal article, Editorial / Opinion, Other / General (target). Medium quality, medium relevance.

Key findings: This editorial discusses the prospect of regulation in the UK governing food produced using CRISPR. The editorial argues that Brexit has presented an opportunity for the UK to move in a different direction from the EU, and in particular that gene-edited technology could (and should) be regulated differently from GM, if it yields a result that could have been produced by conventional breeding. But they do suggest that if the UK does move in this direction, they need to bring the public along, and should avoid a narrative that the change is about cutting red tape or de-regulation — because that could suggest that safety and other concerns are not being taken seriously. Such a narrative could, in turn, impede research and development of an important new technology. The editorial also argues that the UK should consider independent evaluations of the safety and environmental impact of using CRISPR technology in agriculture and food, and share these with other countries.

Nature Biotechnology. (2006). Genetically modified mush. *Nature Biotechnology*, *24*(1), 2. https://doi.org/10.1038/nbt0106-2.

Study details: Scholarly literature, Journal article, Editorial / Opinion, Other / General (target). Low quality, low relevance.

Key findings: This opinion piece documents the cancellation of a CSIRO study on GM peas (due to a potential health implication in mice), and a political reaction to this by the Western Australian agricultural minister. Argues that absolute proof for the safety of GM (or any other) food is a scientific impossibility. We have in place a reliable assessment process to flag potentially allergenic recombinant proteins on a case-by-case basis. And with so many other priorities competing for taxpayer money, one must question whether the best interests of the Western Australian public have really been served.

Nawaz, S., Klassen, S., & Lyon, A. (2020). Tensions at the Boundary: Rearticulating 'Organic' Plant Breeding in the Age of Gene Editing. *Elementa-Science of the Anthropocene*, 8(34), 1-21. https://doi.org/10.1525/elementa.429.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Qualitative, Interviews (0-99 participants), US. High quality, medium relevance.

Key findings: Focus on organic community - selected informants with knowledge. Participants saw GE/NBTs as part of a flawed political/economic system. Informants raised uncertainty about environmental and human risks as a problem with NBTs. Likely to be resistance from organic sector. Paper may be useful in anticipating comments from the organic sector about pre-market assessment of NBT foods: "We trace how the sector is re-articulating boundaries between what are legitimate organic breeding practices or not, and in more implicit ways, between who can participate in deliberation on this topic or not. We find that the organic community opposes gene editing on similar grounds to its historical opposition to GM, thus reasserting the boundary between "organic" and "biotechnological". The sector is also deepening the articulation of this boundary by directly contesting the distinctions that proponents use to differentiate gene editing from GM, such as claims that it might be more democratic or inclusive, and heightened concerns around issues of transparency. We also find that both internal and external pressures are dampening conversations on boundary setting between gene editing and acceptable organic breeding methods. We assert that the reason for the sector's outward unanimous rejection of gene editing is linked, at least in part, to the high stakes of losing consumer trust amidst technically complex and polarizing biotechnology debates, and the need to provide farmers with clear guidelines to follow"

New Zealand Royal Commission on Genetic Modification. (2001). *New Zealand Royal Commission on Genetic Modification: Report*

Study details: Grey literature, Government report, Empirical, Other / General (target), Qualitative, Other (1000+ participants), New Zealand. High quality, medium relevance.

Key findings: Provides evidence from consultations and public submissions as part of the Royal Commission on Genetic Modification. Includes discussion on cultural, ethical, spiritual, environmental, health, economic and research related issues. Also includes Maori perspectives.

Norton, J., Lawrence, G., & Wood, G. (1998a). The Australian Public's Perception of Genetically-Engineered Foods. *Australasian Biotechnology*, *8*(3), 172-181.

Study details: Scholarly literature, Journal article, Empirical, Multiple (target), Qualitative, Survey (1000+ participants), Australia. High quality, medium relevance.

Key findings: Explores Australian perceptions of genetically engineered products. Participants were asked to comment on a range of genetically engineered products, including a tomato which had its own genetic structure altered, cheese using genetically engineered Chymosin, wheat with the Bt gene, a blue rose with genes from another plant, pork with gene sequence of human origin, sheep resistant to blowfly strike and a tomato with a gene sequence from fish. 66% of participants indicated that they had little or no knowledge of genetic engineering. Participants indicated that genetic engineering of plants was more acceptable than genetic engineering of animals and humans (66% of participants supported genetic engineering of plants, 40% supported genetic engineering of animals, 25% supported genetic engineering of humans and 32% believed it was morally correct to use human genes in other organisms). Participants ranked the acceptability of the products in the following order (from most to least acceptable): blue rose, tomato (own genes), sheep, cheese, wheat, tomato (fish genes) and pork - the pork was viewed particularly negatively with 65% of participants believing that it was unacceptable. Findings show that participants viewed the outcomes associated with these products as important but support for them decreased when taking into account the fact that they would be achieved through genetic engineering. When asked about a variety of issues of broader relevance to Australian society (e.g., the drug problem, crime, etc.), genetically engineered foods were considered to be of least importance to participants. 75% of participants believed that accidental release of genetically engineered organisms would cause environmental damage and 56% believed that eating genetically engineered foods would have long term health effects. 86% of participants believed that genetic engineering offered benefits to society whilst 80% of participants believed that genetic engineering posed some risk to society. When asked about the general risks versus benefits of genetic engineering, 52% of participants believed that the risks outweighed the benefits. However, when considering specific applications, the benefits of all products were considered to outweigh the risks, except for pork. Most participants believed that each of the products would not cause environmental damage, although this was not the case for the pork scenario. The tomato (own genes) and cheese were the only two applications which most participants considered to have no long-term health effects. Participants were concerned about eating the remaining foods, particularly the pork. Participants ranked their willingness to purchase the products in the following order (from most to least willing): blue rose, sheep (wool), tomato (own genes), cheese, wheat, tomato (fish genes), and pork - most participants would buy these products, except the pork. 92% of participants supported government oversight of genetically engineered foods and 93% believed that consumers should be consulted before the release of genetically engineered foods. Most participants believed that all products should be labelled. Participants ranked trust in organisations to tell the truth about genetic engineering in the following order (from most to least trustworthy): schools/universities, environmental organisations, animal welfare organisations, consumer organisations, farmers/farm groups, public authorities, religious organisations, industry, the media and political organisations. 73% of participants believed that information from the government about the risks of technology was not honest or reliable whilst 76% believed that information from business and industry about the risks of technology was not honest or reliable.

Norton, J., Lawrence, G., & Wood, G. (1998b). The Australian Public's Perception of Genetically-Engineered Foods - Methodology. *Australasian Biotechnology*, *8*(4), 241-242.

Study details: Methodology paper which relates to the above. No significant further details.

Office of the Gene Technology Regulator. (2015). *Community Attitudes to Gene Technology*.

Study details: Grey literature, Other report, Empirical, Other / General (target), Quantitative, Survey (1000+ participants), Australia. Medium quality, medium relevance.

Key findings: This report, prepared for the Office of the Gene Technology Regulator, presents results of a survey on Australian attitudes to gene technology. The report argues that knowledge about what foods are genetically modified in Australia is generally poor. Findings include that there has been a drop in both awareness and support for gene technologies in Australia since 2012, with mean levels of support dropping from 6.07 out of ten to 5.33. However, there were still more people in support of GMOs generally than were opposed, although this changed with the applications. Support was much greater when the applications were for medical uses (such as producing insulin or vaccines), for industrial uses (such as making biofuels or plastic replacement parts from plants) and for other uses (such as modifying microbes to clean up the environment). Using gene technology in food and crops had far less support than the other applications.

Generally speaking, women were more concerned than men about the possible negative impacts of gene technology, and older people were more concerned than younger people. Dividing the audience into four segments based on their

support for GM foods, almost a half of survey respondents were against the production of GM foods until the science proved it was safe. More than a quarter stated they were open to the production of food this way as long as the regulations were in place to make sure it is safe. Only 15% were completely against the production of GM foods and would never change their minds, and 12% accepted it was safe way to produce food. There has been a significant drop in support for growing GM crops in a person's state from more than 50% support in 2007, 2009 and in 2012 to a low in 2015 of 38%. Most respondents (69%) felt that biotechnology would improve our way of life in the future, while only 46% felt that GMOs would improve our way of life in the future. Almost 3 in 10 felt that GMOs would make things worse in the future. As in previous studies it appears that people with less knowledge of gene technology are less likely to support it. Most support or rejection of GM foods was conditional, and is likely to move based on knowledge of regulation or scientific evidence of safety, indicating that a higher awareness of the OGTR and other regulators, and their roles, would have some impact on public concerns.

As has repeatedly been shown in previous studies, people have different attitudes toward different types of GM, and there is more support for modifications that are perceived to be less radical. When asked about the rules and regulations relating to GM, and whether they were sufficiently rigorous and complied with, there was majority agreement, but also significant don't know responses

Pirscher, F., & Theesfeld, I. (2018). The Ethical Dilemma With Governing CRISP/Cas Genome Editing. In S. Springer & H. Grimm (Eds.), *Professionals in Food Chains* (pp. 419-423). Wageningen Academic Publishers. https://doi.org/10.3920/978-90-8686-869-8_66.

Study details: Scholarly literature, Book chapter, Discussion, Other / General (target), High quality, medium relevance.

Key findings: This paper explores key ethical dilemmas related to governing CRISPR genome editing, particularly with regard to food. The authors argue that fast regulative action is needed to catch up with developments, but that the required social debate around the technology requires time.

Key ethical dilemmas discussed: CRISPR prevents an easy product or process answer to what defines a GMO; We potentially lose the ability to monitor the end product; Reducing the barriers to entry comes with consequences, in both speed of new developments and lower risk mitigation frameworks.

Rabbanee, F. K., Afroz, T., & Naser, M. M. (2021). Are Consumers Loyal to Genetically Modified Food? Evidence From Australia. *British Food Journal*, *123*(2), 803-819. https://doi.org/10.1108/BFJ-11-2019-0832.

Study details: Scholarly literature, Journal article, Empirical, Other / General (target), Quantitative, Survey (100-499 participants), Australia. Medium quality, low relevance.

Key findings: This study aims to explore the factors that influence consumer repurchase intention and behavioural loyalty toward GM food. Findings reveal that overall, consumers were willing to repurchase the selected GM food products and were loyal toward them. Loyalty toward GM food is influenced by the interplay between awareness of benefits and risks, situational and social influences and attitude and repurchase intention. Female consumers are found to not only possess a relatively more favourable attitude and repurchase intention, but also are more loyal toward GM food compared to male consumers. Unlike older consumers, younger consumers' loyalty toward GM food is influenced by their attitude and repurchase intention.

Richardson-Harman, N., Phelps, T., Mooney, P., & Ball, R. (1998). Consumer Perceptions of Fruit Production Technologies. *New Zealand Journal of Crop and Horticultural Science*, *26*(3), 181-192. https://doi.org/10.1080/01140671.1998.9514054.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Qualitative, Survey (500-999 participants), New Zealand. Medium quality, medium relevance.

Key findings: Seeks to understand New Zealand consumers' perceptions of risks and benefits of five fruit production technologies, including genetic engineering, chemical fertilisers, chemical pesticides, organic farming and irradiation. 75-95% of participants indicated that they had prior knowledge of genetic engineering, although 45-85% of participants indicated that they had not heard of transgenic plants/animals (the article provides a breakdown of these factors according to adolescent versus adult and rural versus suburban factors). 81% of participants indicated that they were unsure if they had ever eaten GM foods, 7% thought they had eaten GM foods and 9% were sure they had not eaten GM foods. 27% of participants indicated that they did not want particular plants to be genetically engineered (a third of these people chose New Zealand natives), whilst 11% of participants did not want any plants to be genetically engineered. 24% of participants indicated that they did not want genetic modification to be used for particular plant characteristics (this includes 11% for colour, 11% for shape and 26% for any/all characteristics). Participants indicated that the benefits of genetic engineering in food production outweighed the risks to consumers/the environment/future generations of New Zealanders. However, participants indicated that both scientists and the participants themselves had a lack of knowledge about the risks associated with gene technology (no data on the prevalence of this assertion among participants). 62% of participants indicated that they would eat a GM apple which had been engineered for increased size, 67% for improved flavour and 66% for reduced chemical residues. 38% of participants indicated that they would like GM to be used to improve the flavour of fruits, 48% for reduced pest damage of fruits and 22% for other benefits for fruits (this includes 13% for increased shelf life, 12% for fruit colour and 11% for fruit texture). Medium usefulness as findings tend to be generalised across adult and adolescent participants.

Roberts, M., Haami, B., Benton, R., Satterfield, T., Finucane, M. L., Henare, M., & Henare, M. (2004). Whakapapa as a Maori Mental Construct: Some Implications for the Debate Over GM of Organisms. *Contemporary Pacific*, *16*(1), 1-28. https://doi.org/10.1353/cp.2004.0026.

Study details: Scholarly literature, Journal article, Discussion, Other / General (target), New Zealand. Medium quality, low relevance.

Key findings: The purpose of this paper is to seek an understanding of the underlying principles that inform the concept of whakapapa amongst Māori, and how this applies to the debate about GMO. Using the kumara (sweet potato) as a case study, we attempt to clarify the rationale for the groupings and implied relationships included in this whakapapa, and what those relationships might mean in terms of the modern species concept and scientific classification of organisms. The authors' intention is to further inform public discussion surrounding genetically modified organisms as well as to provide decision makers with a better understanding of how this Maori concept works in this debate. The conclusion is not definitive. "During the ongoing GMO debate, many Maori have voiced the opinion that transmutation of one species into another (including humans into other animals) occurs only in the realm of the atua. In other words, while it is possible for gods to perform such actions, it is not appropriate for humans to attempt the same by moving genes between species. However, Marama and her plants are located in historical time. But it would be unwise to interpret this as evidence in support of transgenic modification. It seems more likely that this story simply seeks to explain why and how Maori were forced to adapt to local and sometimes inferior plant species (pohue, mawhai, and whau) in place of those (kumara, hue, and aute, respectively) brought from Eastern Polynesia..."

Rogers-Hayden, T. (2005). Asilomar's Legacy in Aotearoa New Zealand. *Science as Culture*, *14*(4), 393-410. https://doi.org/10.1080/09505430500369152.

Study details: Scholarly literature, Journal article, Discussion, Other / General (target). Medium quality, low relevance.

Key findings: This paper questions what effect Asilomar had on GM regulation in Aotearoa, including type of regulation, and why and how this came about. Argues that a strong influence on New Zealand's GM development can be explained as the legacy of the science-society relationship embodied by Asilomar, which led to the scientization of the debate and self-regulation situated within the context of New Zealand's local narratives: complex social, ethical and spiritual issues were reduced to a narrow set of technical matters. This also meant that debate could occur only within the sciences, following a deficit model of communication.

Saleh, R., Bearth, A., & Siegrist, M. (2021). How Chemophobia Affects Public Acceptance of Pesticide Use and Biotechnology in Agriculture. *Food Quality and Preference*, *91*, 1-10. https://doi.org/10.1016/j.foodqual.2021.104197.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Quantitative, Survey (500-999 participants), Europe. Medium quality, low relevance.

Key findings: This study examines consumer acceptance of pesticide use in conventional and organic agriculture and agri-biotech applications as crop-protection measures. The "gene transfer" group (M =68.90, SD =27.92) had significantly higher acceptance than the "synthetic pesticides" (M =50.83, SD =27.47), "natural pesticides" (M =55.62, SD =26.26) and "gene editing" (M =52.39, SD =26.95) groups. Consumers were most willing to accept gene transfers as a protection measure, provided the gene came from a wild variety of the same species as the cultivated plant. Both chemophobia and the importance of naturalness in food influence consumer acceptance of pesticide use and agri-biotech applications. Participants' acceptance of the investigated crop-protection measures was largely influenced by their naturalness perceptions. Participants perceived gene transfers as more natural and acceptable than pesticide use and gene editing. Chemophobics who oppose pesticides might also fear and oppose agri-biotech applications is plausible.

Schibeci, R. (1999). Public perceptions of biotechnology: Toward a dialogue. *Australasian Biotechnology*, *9*(2), 95-97.

Study details: Scholarly literature, Journal article, Empirical, Multiple (target), Qualitative, Focus group. Low quality, low relevance.

Key findings: Low quality paper with very minimal information about methodology or findings from focus groups.

Schibeci, R., & Harwood, J. (2007). Stimulating Authentic Community Involvement in Biotechnology Policy in Australia. *Public Understanding of Science*, *16*(2), 245-255. https://doi.org/10.1177/0963662506067909.

Study details: Scholarly literature, Journal article, Discussion, Other / General (target), Australia. Medium quality, medium relevance.

Key findings: This paper analyses community involvement in biotechnology policy in Australia, specifically examining the Gene Technology Act 2000 and the roles of the Office of the Gene Technology Regulator and the Gene Technology Community Consultative Committee. The paper argues that the institutions that underpin biotechnology policy serve to hamper community involvement and reinforce a cognitive deficit model of community involvement. Argues there is a

history of deficit model communication in Australia and on this sort of topic, such as by CSIRO and by Biotechnology Australia, and that this is due to institutional design. The authors propose that the situation could be turned around so that interested citizens can participate in authentic community involvement in biotechnology policy in Australia. To do this they argue: - broader concept of risk needs to be adopted to take into account social and economic risks (as well as health, safety and environmental); - key regulators and decision makers should allow wider communication and dissent amongst committees; - consider citizens' juries.

Scully, J. (2003). Genetic Engineering and Perceived Levels of Risk. *British Food Journal*, *105*(1-2), 59-77. https://doi.org/10.1108/00070700310467492.

Study details: Scholarly literature, Journal article, Empirical, Other / General (target), Mixed methods, Interviews (100-499 participants), New Zealand. Medium quality, low relevance.

Key findings: The study found that most consumers are uninformed about genetic engineering and the potential benefits it holds. Across the entire sample only 19.4% could correctly define genetic engineering as a transgenic gene transfer (non-natural) and 42.6% gave a general comment about genes and modification of final product. "Of those surveyed, 28% agreed that there are definite benefits associated with genetically engineered food while 37% disagreed with this statement This study, carried out in Christchurch, New Zealand, explores the role of consumers opinions, attitudes and behaviours toward genetic engineering. It focuses on the relative perceived risk associated with consuming genetically engineering food and the role of food labelling in reducing this risk. The opinion statement, 'The risks from consuming genetic engineered food is unknown' was agreed to by 75% of respondents. Eight percent disagreed with this. However, when asked if the risks to consumers' health were low from eating genetically engineered foods, 22% of respondents were inclined to agree.

The question of whether genetically engineered food should be labelled was almost unanimous, with 90 percent agreeing that it should be labelled. Only 5percent disagreed and the remainder were unsure. Of the respondents, 87percent thought the government should legislate the labelling of all food to indicate whether it had been genetically modified ","The level of acceptance seemed to be determined by the degree of knowledge people had about the processes behind genetic engineering and its application. One-way ANOVA revealed that whether people could accurately define genetic engineering, or give a very general explanation and include some scientific words or had no idea, had a significant impact on the consumers' level of acceptance.

Labelling is a very important communication medium, which if used effectively could have important implications in risk minimisation of genetically engineered foods. Labelling of genetically modified foods was a welcome addition to food packages by a significant majority of respondents, with most people willing to pay something toward this.

Shew, A. M., Danforth, D. M., Nalley, L. L., Nayga, R. M., Tsiboe, F., & Dixon, B. L. (2017). New Innovations in Agricultural Biotech: Consumer Acceptance of Topical RNAi in Rice Production. *Food Control*, *81*, 189-195. https://doi.org/10.1016/j.foodcont.2017.05.047.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Quantitative, Survey (100-499 participants), Australia. High quality, high relevance.

Key findings: Participant discounted food (rice) produced with an RNAi pesticide spray more than conventional (synthetic spray) but less than GM Bt rice. 80% surveyed said they would eat food produced with this RNAi technology. They did include education etc but not significant for any other then in the US. Australia education seemed to slightly increase the discount. "This paper looks at RNAi (an NBT) in a pesticide applied to a food crop, rather than a food crop per se. That said - also has recent data on WTP Bt rice versus conventional rice. I suspect that this application would actually go to APVMA rather than FSANZ but not sure.

Shew, A. M., Nalley, L. L., Snell, H. A., Nayga, R. M., & Dixon, B. L. (2018). CRISPR Versus GMOs: Public Acceptance and Valuation. *Global Food Security-Agriculture Policy Economics and Environment*, *19*, 71-80. https://doi.org/10.1016/j.gfs.2018.10.005.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Quantitative, Survey (100-499 participants), Australia. High quality, high relevance.

Key findings: This paper compares acceptance of a CRISPR-derived glyphosate-tolerant rice with the same product developed through GM in 5 countries including Australia. The Australian data reveals that knowledge of CRISPR is much lower than GM, but WTC and WTP are similar. This is the ONLY study that looks at Australian acceptance of an NBT in food crop. 12.6% of participants responded that they had "heard" of CRISPR (compared to 68.2% for GM)", 49.8% said CRISPR safe compared to 6.3% said GM safe, 59.9% wiling to consumer CRISPR rice versus 57.7% for GM rice. No significant difference for WTP for CRISPR of GM rice (i.e., similar discounts), 4.3% agreed with CRISPR helps solve environmental problems (8.6% for GM).

Small, B. H., & Fisher, M. W. (2005). Measuring Biotechnology Employees' Ethical Attitudes Toward a Controversial Transgenic Cattle Project: The Ethical Valence Matrix. *Journal of Agricultural and Environmental Ethics*, *18*(5), 495-508. https://doi.org/10.1007/s10806-005-0904-z.

Study details: Scholarly literature, Journal article, Empirical, Food animals, Quantitative, Survey (100-499 participants), New Zealand. Medium quality, low relevance.

Key findings: This paper explores the pathways of acceptance amongst biotechnology employees of a controversial transgenic project. Results suggest that, for employees of a biotechnology organization, ethical reasonings (non-harm most important, and then benefit and justice) had most impact on acceptance.

Small, B. H., Parminter, T. G., & Fisher, M. W. (2005). Understanding Public Responses to Genetic Engineering Through Exploring Intentions to Purchase a Hypothetical Functional Food Derived From Genetically Modified Dairy Cattle. *New Zealand Journal of Agricultural Research*, *48*(4), 391-400. https://doi.org/10.1080/00288233.2005.9513672.

Study details: Scholarly literature, Journal article, Empirical, Food animals, Quantitative, Survey (1000+ participants), New Zealand. Medium quality, medium relevance.

Key findings: This article looks at WTP for a hypothetical cow genetically modified to produce milk giving consumers protection from gastroenteritis or food poisoning.

A clear result of this study, and in keeping with other similar surveys, was that respondents were overwhelmingly sceptical or negative about genetic engineering in general.

The high number of 'don't know' responses to some, but not all, questions in this survey (particularly those about the outcomes of the technology), may represent a high level of genuine uncertainty in the community. Approximately 55% of the sample (n = 1684) would not have purchased the product, 20% would have, while a further 22% were neutral.

Intention to purchase was correlated with both an individual's General Attitude to Genetic Engineering (R = 0.78), and their Product-specific Attitude (R = 0.83). The Product-specific Attitude explained significantly greater variance in Purchase Intention than General Attitude, indicating the value of case-by-case assessment.

The General Attitude scale was comprised of Intrinsic Moral Values to Genetic Engineering, Outcome Beliefs regarding the technology, Trust in Authorities, and Perception of Social Norms constructs or subscales. These four constructs were strongly correlated to Purchase Intention (R = 0.73, 0.70, 0.61, and 0.64, respectively).

Genetic engineering will not be acceptable if it harms people, the environment or animals, companies must be held accountable for any harms, and food produced in this way must be labelled. Genetic engineering did not fit with New Zealand's clean-green image, an important part of national self-identity.

Son, E., & Lim, S. S. (2021). Consumer Acceptance of Gene-Edited Versus Genetically Modified Foods in Korea. *International Journal of Environmental Research and Public Health*, *18*(7), 1-17. https://doi.org/10.3390/ijerph18073805.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Quantitative, Survey (100-499 participants), Other location. Medium quality, high relevance.

Key findings: Approximately 85% of the respondents responded that they had heard of GM, whereas less than half, at less than 45%, were aware of gene editing. This paper surveys a Korean sample to compare acceptance and WTP of GM and gene edited food, in particular soybean oil. Estimated results suggest that consumers tend to accept gene-editing more than genetically modified foods. 51% of the respondents, the largest group, responded that gene editing technology is safer, whereas 7%, the smallest group, responded that GM technology was safer than gene editing technology. WTP lowest for GM food and clothing, gene edited food tends to be higher (conventional the highest) Acceptance of novel technology is shown to correspond closely to the degree of consumers' scientific knowledge. Results also show that country of origin is a significant food-specific attitudinal factor in shaping consumer preference - when purchasing food products rather than non-food products, the respondents regarded the origin of raw material as more important than the production technology. This paper also includes a very interesting table summarising studies comparing consumer evaluation of GM and gene edited foods.

Tabei, Y., Shimura, S., Kwon, Y., Itaka, S., & Fukino, N. (2020). Analyzing Twitter Conversation on Genome-Edited Foods and Their Labeling in Japan. *Frontiers in Plant Science*, *11*(535764), 1-10. https://doi.org/10.3389/fpls.2020.535764.

Study details: Scholarly literature, Journal article, Empirical, Other / General (target), Mixed methods, Media study (1000+ participants), Other location. Medium quality, low relevance.

Key findings: Japanese tweeting about genome edited food peaks following influential events. 54.5% to 62.8% of tweets were negative about genome-edited food and the labelling policy of the Consumer Affairs Agency, respectively,

indicating in particular a strong demand for mandatory labelling. Argues that knowledge leads to greater acceptance, but without evidence.

Tamaki, R., & Batt, P. J. (2013). Consumers' Perceptions, Attitude and Behaviour Toward Fair Trade and Organic Coffee in Western Australia and Japan. In P. J. Batt (Ed.), *IV International Symposium on Improving the Performance of Supply Chains in the Transitional Economies* (Vol. 1006, pp. 363-372).

Study details: Scholarly literature, Conference paper / proceedings, Empirical, Other / General (target), Qualitative, Survey (100-499 participants), Australia. Medium quality, low relevance.

Key findings: Comparison of WesternA and Japanese consumers' attitudes toward and willingness to buy fair trade and organic coffee.

ustralian WA participants were more concerned about the absence of genetic modification in fair trade and organic produce than Japanese participants. When asked about what organic means to them, only 4.7% of WA participants chose non-GM.

Tizard, M., Hallerman, E., Fahrenkrug, S., Newell-McGloughlin, M., Gibson, J., de Loos, F., Wagner, S., Laible, G., Han, J. Y., D'Occhio, M., Kelly, L., Lowenthal, J., Gobius, K., Silva, P., Cooper, C., & Doran, T. (2016). Strategies to Enable the Adoption of Animal Biotechnology to Sustainably Improve Global Food Safety and Security. *Transgenic Research*, *25*(5), 575-595. https://doi.org/10.1007/s11248-016-9965-1.

Study details: Scholarly literature, Journal article, Discussion, Food animals. High quality, medium relevance.

Key findings: This paper explores the main barriers to the adoption of animal biotechnology (including NBTs), tactics for navigating those barriers, strategies to improve public perception and trust, as well as industry engagement and actions for governments and trade organisations to harmonise regulations and trade agreements.

Barriers: - Current regulation is diverse and difficult to navigate; - Transgenic animals seem more acceptable in therapeutic settings; - The costs of generating the data necessary for regulatory approval is a major barrier, as food products tend to be marketed with lower profit margins (than medicines); - Length of time required for regulatory approval; - Lack of international regulatory harmonisation; - Significant differences in acceptance in different parts of the world; - Public attitudes.

To achieve this goal, cooperation, education, and communication between multiple stakeholders—including scientists, industry, farmers, governments, trade organizations, NGOs and the public is necessary. Suggestions include:- Resolution of where the threshold is set to require regulation will have a significant impact on the development and degree of adoption of precision breeding in a particular country;- Harmonise regulation amongst OECD member states;- Fostering a positive attitude toward new and existing technology from the public is predicated on segments of the general public (e.g., those who suffer from food allergies or intolerance) actively acknowledging a personal need for the technology and those people advocating for the benefits to which they currently do not have access;- Foster (and communicate) potential animal welfare benefits;- Demonstrate a high level of consensus among scientific institutions, industry and regulators. Argument here is that a lack of consensus amongst 'authorities' increases perception of risk. To arrive at consensus, public education will need to shift from focusing on the complex details of the science to straightforward explanations using real-world examples which simultaneously provide simple and accurate information while highlighting the positive outcomes that the science is capable of producing;- Foster dialogue amongst key stakeholders;- Develop a clear delineation and understanding of the differences between traditional transgenic methods and techniques like precision breeding and other emerging technologies.

Tranter, M. (2003). A Question of Confidence: An Appraisal of the Operation of the Gene Technology Act 2000. *Environmental and Planning Law Journal*, *20*(4), 245-259.

Study details: Scholarly literature, Journal article, Discussion. Medium quality, low relevance.

Key findings: This article examines the Gene Technology Act 2000 (Cth) and its operation during its short existence. The author argues that a regulatory regime in the controversial area of gene technology should engender the confidence of the public and industry if the innovative technology is to be accepted, especially in relation to food crops. The author points to this being acknowledged in the formulation of the Act: "lack of credibility (particularly in relation to the assessment and management of GMOs for release into the environment) may... harm the ability of industry to market GMOs and GM products assessed as safe"

However, the author argues that the Act lacked any consideration of economic or marketing implications - the scientific assessment of risks should, the author argues, be related to economic or marketing factors for the industry. Similarly, the declaration or threatened declaration by some States of moratoriums on the commercial release of GMOs can cause complications.

Ufer, D., Ortega, D. L., & Wolf, C. A. (2019). Economic Foundations for the Use of Biotechnology to Improve Farm Animal Welfare. *Trends in Food Science & Technology*, *91*, 129-138. https://doi.org/10.1016/j.tifs.2019.07.002.

Study details: Scholarly literature, Journal article, Review, Food animals. Medium quality, medium relevance.

Key findings: The objective of this study is to explore the economic foundations for employing biotechnology to improve farm animal welfare and evaluate potential consumer response to such applications. The study reviews relevant literature to answer this question.

Key argument is that the intersection of biotechnology and animal welfare creates a unique situation for consumers as they evaluate tradeoffs. On one hand, consumers demonstrate a clear dislike toward genetic and hormonal biotechnology applications in agriculture, resulting in significant discounting of products produced using gene editing technologies among other biotechnologies. On the other hand, consumers are demanding ever-increasing levels of animal welfare and are willing to pay premiums to assure the livestock responsible for their food were raised in accordance with acceptable welfare standards. These counteracting effects may represent an opportunity for a compromise amongst consumers and producers.

If the benefits of biotechnological applications in agriculture are both welfare- and profit-increasing, producers may be able to capitalize on profitable biotechnologies while meeting consumer demands for improved welfare. However, it is yet unknown whether the welfare benefits will be communicated effectively to offset consumer objections to biotechnology or if consumer aversion to biotechnology is stronger than preferences for improved animal welfare.

Vanbergen, A. J., Aizen, M. A., Cordeau, S., Garibaldi, L. A., Garratt, M. P. D., Kovacs-Hostyanszki, A., Lecuyer, L., Ngo, H. T., Potts, S. G., Settele, J., Skrimizea, E., & Young, J. C. (2020). Transformation of Agricultural Landscapes in the Anthropocene: Nature's Contributions to People, Agriculture and Food Security. *Advances in Ecological Research*, *63*, 193-253. https://doi.org/10.1016/bs.aecr.2020.08.002.

Study details: Scholarly literature, Book chapter, Discussion, Other / General (target). Medium quality, low relevance.

Key findings: This paper looks at pathways identified in the literature to sustainable agriculture. NBTs are discussed as one possible option, and the authors argue that to reverse the ecological degradation of agricultural lands seen worldwide and to shift it toward a sustainable system will require that nature-based approaches, like those under the umbrella of ecological intensification, are placed at the core of future agricultural management, but also the entire food system and value chains. This does not preclude a role for novel technologies that help to optimise or facilitate increased production, but future technologies must be applied alongside nature-based solutions in a systems approach and work within the limits of the ecological landscape. Moreover, it is important to emphasise that no one solution is universally applicable given the socio-economic and ecological heterogeneity worldwide, instead a future agricultural system should comprise a suite of options applied in the most efficient, but environmentally sustainable and resilient way for each context.

Van Eenennaam, A. L., & Young, A. E. (2018). Gene Editing in Livestock: Promise, Prospects and Policy. *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources*, *13*(27), 1-14. https://doi.org/10.1079/PAVSNNR201813027.

Study details: Scholarly literature, Journal article, Discussion. Medium quality, low relevance.

Key findings: This article reviews research on gene editing in livestock. While much of the paper talks of scientific progress, it also explores US regulation. In particular, it argues that the US FDA's 2017 Draft Guidance 187 on the 'Regulation of Intentionally Altered Genomic DNA in Animals' is at odds with the intended US approach for gene edited plants and with emerging regulations for gene edited animals in other countries. These regulatory agencies have stated that they do not plan to impose additional regulatory oversight on gene edited plants that do not contain novel DNA sequences (i.e., rDNA constructs) and which could have been obtained through conventional breeding (e.g., backcrossing or radiation mutagenesis).

The authors ask, "what is the rationale for regulating a genetic trait produced using gene editing while not regulating that same trait produced by classical breeding techniques, if the risks are the same in each case".

The authors note quite usefully that the early applications that successfully navigate regulatory hurdles will influence the public discussion around gene edited animals and impact the trajectory of future applications.

van Mil A, Hopkins H, Kinsella S. (2017). *Potential Uses for Genetic Technologies: Dialogue and Engagement Research Conducted on Behalf of the Royal Society.* Hopkins Van Mil.

Study details: Grey literature, Other report, Empirical, Other / General (target), Qualitative, Survey (1000+ participants), UK. High quality, high relevance.

Key findings: Results of a deliberative public dialogue and survey conducted in the UK. Generally looking at genetic technologies as a whole, although does contain some data on genome editing specifically. Also provides data on trust in those responsible for developing/regulating genetic technologies. 81% of survey participants believe that there should be stricter regulation of genome editing for plants and animals to ensure the resulting food is safe for human

consumption. 79% of survey participants agree that genome editing opens up new opportunities to tackle global challenges. 50% of survey participants disagree that the use of genome editing to tackle global challenges is morally wrong. However, 46% of survey participants agree that genome editing carries too many risks to be used to tackle global challenges. Most survey participants disagreed with the use of genome editing in animals and plants for cosmetic reasons. 70% of survey participants supported the use of genome editing in animals to prevent disease in livestock whilst 56% of survey participants supported the use of genome editing in animals to prevent crop damage.

Wheeler, S. A. (2007). Contrasting the Beliefs of Australian Agricultural Professionals About the Benefits and Costs of Genetic Engineering and Organic Agriculture. *Australian Journal of Experimental Agriculture*, *47*(12), 1389-1396. https://doi.org/10.1071/ea06294.

Study details: Scholarly literature, Journal article, Empirical, Other / General (target), Qualitative, Interviews (100-499 participants), Australia. High quality, medium relevance.

Key findings: Seeks to understand Australian agricultural professionals' attitudes toward genetic engineering and organic agriculture. Found that agricultural professionals tended to be more supportive of genetic engineering than organic agriculture. The most common benefits associated with genetic engineering were increased production, improved pest and disease management, increased future potential of the technology, improved quality and reduced chemicals. 77% of participants believed that genetic engineering will improve yields compared to conventional agriculture. Almost half of the participants indicated that their views toward genetic engineering had not changed over the past 5 years, with around a quarter indicating that their views had become more favourable and a quarter less favourable. 87% of participants believed that the use of genetic engineering may impose major costs/risks on society. The most common costs associated with genetic engineering were risk and uncertainty issues, environmental factors, public and regulatory attitudes, farm issues and social factors. Only 6% of participants indicated that health factors were a major cost of genetic engineering. When asked whether the benefits of genetic engineering outweighed the costs, there was a roughly equal number of participants who agreed and disagreed with this statement, whilst approximately one third was unsure. Paper also provides a more detailed breakdown of opinions expressed by general versus target samples.

Wheeler, S. A. (2009). Exploring the Influences on Australian Agricultural Professionals' Genetic Engineering Beliefs: An Empirical Analysis. *Journal of Technology Transfer*, *34*(4), 422-439. https://doi.org/10.1007/s10961-008-9094-y.

Study details: Scholarly literature, Journal article, Empirical, Other / General (target), Qualitative, Interviews (100-499 participants), Australia. High quality, medium relevance.

Key findings: Seeks to understand Australian agricultural professionals' attitudes toward genetic engineering. Those both for and against genetic engineering had similar subjective levels of knowledge about genetic engineering (in other words, there was no correlation between subjective knowledge and overall attitudes toward genetic engineering). However, there was a correlation between higher subjective knowledge and belief that genetically engineered products were more financially profitable and that there was no need for more long-term testing of genetically engineered products before further release. Participants who were either for or against genetic engineering reported higher levels of subjective knowledge compared to participants who were unsure about genetic engineering. There was a correlation between support for genetic engineering and participants who were scientists in their 50s and above, were non-European, had a higher percentage of research spent on genetic engineering, believed in environmental superiority/financial profitability of biotechnology products and believed that intellectual property rights/patenting were good for agricultural research. Conversely, there was a correlation between opposition to genetic engineering and participants with a farm background who were middle aged, believed that conventional agriculture is environmentally unsustainable and believed that there should be more long-term research on biotechnology products/systems before further release. 25% of participants in the general sample of agricultural professionals disagreed that the benefits of genetic engineering outweighed the costs/risks (this increased to 44% in the targeted sample).

Wheen, N. R. (2004). Genetic Modification, Risk Assessment, and Maori Belief Under New Zealand's Hazardous Substances and New Organisms Act 1996. *Asia Pacific Journal of Environmental Law*, *8*(3-4), 141-176.

Study details: Scholarly literature, Journal article, Discussion, Food animals. Medium quality, low relevance.

This article examines the decision-making record of New Zealand's Environmental Risk Management Authority concerning proposals to develop and field-test genetically modified cattle. The author finds that the Authority's approach overvalues science and undervalues cultural and social issues, and suggests that this could result in the Authority losing the necessary community confidence to support the development of biotechnology in New Zealand.

Williams, P., Stirling, E., & Keynes, N. (2004). Food Fears: A National Survey on the Attitudes of Australian Adults About the Safety and Quality of Food. *Asia Pacific Journal of Clinical Nutrition*, *13*(1), 32-39.

Study details: Grey literature, Journal article, Empirical, Other / General (target), Quantitative, Survey (1000+ participants), Australia. Low quality, medium relevance.

Key findings: 14% of survey participants concerned about GM food (in the unprompted part of the survey) - also 21% concerned about ag chem residues. "Yet in this survey consumers were just as likely to be concerned about those aspects that are well regulated and subject to thorough approval (such as additives and pesticides) as they were concerned about the more realistic threats from food hygiene problems"

Did note that people felt more concerned than they had been "five years ago". Note it uses market research company, did not seek institutional ethics and is funded by "equal artificial sweetener" which are all fine of course but does make this lower quality - unsure if has been peer-reviewed so recommend treating as grey literature. Main point for FSANZ is that people less concerned about GM than other issues"

Wolter, F., & Puchta, H. (2017). Knocking Out Consumer Concerns and Regulator's Rules: Efficient Use of CRISPR/Cas Ribonucleoprotein Complexes for Genome Editing in Cereals. *Genome Biology*, *18*(43), 1-3. https://doi.org/10.1186/s13059-017-1179-1.

Study details: Scholarly literature, Journal article, Editorial / Opinion, Other / General (target). Low quality, low relevance.

Key findings: This opinion / editorial argues that NBTs (specifically CRISPR/ Cas ribonucleoproteins (RNPs) to achieve selection-free site-directed mutagenesis) cannot, from a scientific point of view, be regarded as GMO.

"Two recent publications in Nature Communications demonstrate that the use of RNP-mediated editing is now possible for two of the world's most important crop plants, and that the farming of the resulting plants with improved traits should not be blocked by regulation hurdles worldwide as they cannot be regarded as genetically modified organisms (GMOs)."

Without significant exploration, the authors argue that resultant crops should be more acceptable. "

Wolt, J. D., & Wolf, C. (2018). Policy and Governance Perspectives for Regulation of Genome Edited Crops in the United States. *Frontiers in Plant Science*, *9*(1606), 1-12. https://doi.org/10.3389/fpls.2018.01606.

Study details: Scholarly literature, Journal article, Discussion, Other / General (target). Medium quality, low relevance.

Key findings: This paper reviews the existing regulatory regime covering biotechnology-derived plants in the United States. The authors argue that existing regulations are vague and ambiguous in their application to new technology, especially genome edited crops. Regulators and others who wish to interpret existing and pending statutes are faced with a quandary. It is not obvious, a priori, to include genome edited organisms under existing regulations covering genetically engineered products, or as "products of biotechnology," a term with shifting meaning as applied in law. The problem is one of legal interpretation in the context of regulatory decision making.

Worsley, A., & Lea, E. (2008). Consumer Concerns About Food and Health Examination of General and Specific Relationships With Personal Values and Demographics. *British Food Journal*, *110*(10-11), 1106-1118. https://doi.org/10.1108/00070700810918018.

Study details: Scholarly literature, Journal article, Empirical, Other / General (target), Quantitative, Survey (1000+ participants), Australia. High quality, medium relevance.

Key findings: This paper examined the relationship between food concerns and personal values via survey of 1000 South Australians circa 2008. Although it examines GM, the value sets identified might give insight into likely responses to NBT. Also provides context with other food issues. The main aim of this paper was to examine the relationship between personal values and concerns, and did not look at attitudes to GM per se Participants were more concerned about other issues: The most commonly endorsed concern was "clean handling of food in the shops," followed by a number of food safety items and the honesty of food labels. Items associated with least concern were driftnet fishing, imports of foreign foods, GM, and irradiation of foods.

Yang, Y., & Hobbs, J. E. (2019). The Power of Stories: Narratives and Information Framing Effects in Science Communication. *American Journal of Agricultural Economics*, *102*(4), 1271-1296. https://doi.org/10.1002/ajae.12078.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Quantitative, Survey (500-999 participants), Other location. Medium quality, high relevance.

Key findings: This paper explores the impact of communication interventions on preferences for novel food attributes and technologies, finding that information format (logical-scientific versus narrative) matters: narratives help reduce negative perceptions regarding agricultural and food technologies, though they don't appear to be considered more trustworthy or credible. Difference in credibility and trust between type of explanation elevated when selecting type of communication, suggesting again that the type of message should be tailored for different audiences.

Prior to communication intervention, a slight preference for gene editing (12.3% chose) over GM apple (9%), but an inconsistency between attributes and technologies. All three novel food technologies–two plant breeding techniques gene editing and GM, and one food processing method edible coating–are discounted by consumers, a result consistent with prior research on technology neophobia. What is more interesting, and potentially of some comfort to agricultural

and food scientists, is that the resistance to gene editing technology appears to be significantly milder than to GM and an edible coating, suggesting a "window of acceptance" may be available in which to provide constructive, positive communication about this new technology.

Yang, Y., & Hobbs, J. E. (2020a). How Do Cultural Worldviews Shape Food Technology Perceptions? Evidence From a Discrete Choice Experiment. *Journal of Agricultural Economics*, *71*(2), 465-492. https://doi.org/10.1111/1477-9552.12364.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Quantitative, Survey (500-999 participants), Other location. High quality, high relevance.

Key findings: This paper examines the influence of cultural values on food choice behaviours, comparing gene editing, GM and edible coating on apples. The use of gene editing results in negative marginal utilities in a food choice situation, but the effect is not as large as with GM. WTP values are all negative, representing the implicit WTP to avoid three novel food technologies. For example, the sample population is willing to pay $1.31 more for a 500 g bag of pre-packaged apple slices that is not produced with gene editing, and $2.33 to avoid genetically modified apples. Consumers are willing to pay more to avoid GM and edible coating than to avoid gene editing. Pre-existing cultural values are found to be significant determinants of choice behaviours. A 'Hierarchical-Communitarian' requires the lowest monetary compensation to consume foods produced by gene editing (-.96), GM (-1.71) or edible coating (-1.8), while an 'Egalitarian-Individualist' requires the greatest compensation (-1.74, -3.36, -3.05, respectively). That is, 'Hierarchical-Communitarians' are more likely to place a higher value on novel food technologies relative to 'Egalitarian-Individualists', and the 'Hierarchical-Individualists' and 'Egalitarian-Communitarians' lie somewhere in between the two groups. It is clear that individuals belonging to different cultural groups exhibit different attitudes toward food technologies.

Suggestion there is scope to ameliorate potentially negative reactions to the technology with value-compatible messages.

Yang, Y., & Hobbs, J. E. (2020b). Supporters or Opponents: Will Cultural Values Shape Consumer Acceptance of Gene Editing? *Journal of Food Products Marketing*, *26*(1), 17-37. https://doi.org/10.1080/10454446.2020.1715316.

Study details: Scholarly literature, Journal article, Empirical, Food plants, Quantitative, Survey (500-999 participants), Other location. Medium quality, high relevance.

Key findings: Drawing upon Cultural Cognition Theory, the paper examines the influence of cultural worldviews on consumer acceptance of gene editing. Cross breeding most natural, most acceptable, safest (4.29 on Likert scale 1-6, 4.72, 4.66), gene editing next (2.47, 3.39, 3.37), then transgenics (1.95, 2.78, 2.73), then mutagenesis least (1.64, 2.27, 2.12). A hierarchical (versus egalitarian) worldview, positive attitudes toward science and technology, and lower levels of prior risk perceptions influence public acceptance of gene editing techniques.

Yunes, M. C., Osório-Santos, Z., von Keyserlingk, M. A. G., & Hötzel, M. J. (2021). Gene Editing for Improved Animal Welfare and Production Traits in Cattle: Will This Technology Be Embraced or Rejected by the Public? *Sustainability*, *13*(4966), 1-20. https://doi.org/10.3390/su13094966.

Study details: Scholarly literature, Journal article, Empirical, Food animals, Qualitative, Interviews and survey (500-999 participants), Other location. High quality, high relevance.

Key findings: This paper provides an analysis of Brazilian attitudes toward three applications of gene editing in cattle, namely cattle that produce offspring without horns, heat resistant cattle and cattle with increased muscle tissue. Study involved interviews and an online survey. Results may be skewed considering the relatively high level of participants with university education. Participants generally did not support the use of gene editing in these scenarios (cattle with increased muscle tissue was the least accepted scenario). Support for gene editing declined if it was considered to be harmful in terms of animal welfare, was driven by profit or was considered to reinforce the status quo of intensive livestock systems. Interview participants considered gene editing to be unnatural. Interview participants were more supportive of gene editing if they believed that it reduced animal suffering (the reverse was also true as participants were less supportive of gene editing applications which were considered to be harmful to animals). Only 33% of survey participants indicated that they had read much about gene editing of plants, animals or humans. Most survey participants believed that the risks of the gene editing scenarios outweighed the benefits (e.g., 68% of participants believed that there were high risks associated with the scenarios compared to 27% who believed there were high benefits). Participants who were male, of a younger age, were meat consumers, were involved in livestock production and had higher incomes tended to be more supportive of all three gene editing scenarios (although this is somewhat contradicted by later claim that women and younger participants were less supportive of gene editing). Participants with higher levels of education also tended to be more supportive of gene editing. On the other hand, those participants who were concerned about biological and societal risks were less supportive of gene editing. Participants tended to view academia as more trustworthy than government, companies and NGOs when it comes to supplying information about gene editing. Authors point out that, once people are made aware of the realities of animal production processes, they may become more critical of the industry itself. Authors also note that the absence of foreign DNA among the examples chosen did not appear to have an impact on participants' perceptions of their naturalness. Authors believe

that the introduction of gene editing into livestock production in Brazil would not initially result in a strong public backlash although it may result in increased concern over animal production processes (this may drive consumers to purchase non-gene edited products or to avoid animal products altogether).

Yunes, M. C., Teixeira, D. L., von Keyserlingk, M. A. G., & Hotzel, M. J. (2019). Is Gene Editing an Acceptable Alternative to Castration in Pigs? *Plos One*, *14*(6), 1-18. https://doi.org/10.1371/journal.pone.0218176.

Study details: Scholarly literature, Journal article, Empirical, Food animals, Mixed methods, Survey (500-999 participants), Other location. High quality, high relevance.

Key findings: This paper explores public acceptability of gene modification for castration of male pigs in Brazil. 56% considered gene modification of male pigs for this reason acceptable. Acceptability lower among participants who grew up in agricultural environments, but not influenced by sex, age, religion, urban or rural living, or level of education. Acceptability of gene modification of male pigs as an alternative to surgical castration was positively related to the perception of benefits ($r=-0.56$, $\rho<0.0001$) and negatively related to the participant's perception of risks ($r=-0.35$, $\rho<0.0001$). Acceptability was not related to knowledge of basic concepts of genetic biotechnologies ($r=0.06$, $\rho<0.14$), or to awareness of issues related to pig castration or boar taint ($r=0.03$, $\rho<0.44$), both of which were low among participants. Participants that considered gene modification of pigs acceptable justified their position using arguments that it improved animal welfare. Less support was shown for gene editing for other purposes (e.g., producing more meat). In contrast, those that were not in favour were generally opposed to GM. Unforeseen downstream consequences and loss of naturalness was a major concern raised by over 80% of participants. Findings suggest that perceived animal welfare may encourage public support of gene editing of food animals. However, potential risks of the technology need to be addressed and conveyed to the public, as many participants requested clarification of such risks as a condition for support.

6. Additional references

This list covers literature referenced in this report, but not included in the systematic review. All literature in the systematic review is listed above in 5: Annotated bibliography.

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Brent P., Bittisnich D., Brooke-Taylor S., Galway N., Graf L., Healy M., & Kelly L. (2003). Regulation of Genetically Modified Foods in Australia and New Zealand. *Food Control*, *14*(6), 409-416.

FSANZ. (2020). *Food derived using new breeding techniques – review*. Available from https://www.foodstandards.gov.au/consumer/gmfood/Pages/Review-of-new-breeding-technologies-.aspx, accessed 17 June 2021.

Kahan, D. M. (2012). Cultural cognition as a conception of the cultural theory of risk. In S. Roeser, R. Hillerbrand, P. Sandin, & M. Peterson (Eds.), *Handbook of Risk Theory* (pp. 725–759). Dordrecht, The Netherlands: Springer.

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Moher D., Liberati A.., Tetzlaff J, & Altman D. G., The PRISMA Group. (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLoS Med* 6(7), e1000097. https://doi.org/10.1371/journal.pmed.1000097.

Olofsson A., Öhman S., & Rashid S. (2006). Attitudes to Gene Technology: The Significance of Trust in Institutions. *European Societies*, *8*(4), 601-624. DOI: 10.1080/14616690601002707.

POSTNote. (2017). New Breeding Techniques. *UK Houses of Parliament*. Available from https://researchbriefings.files.parliament.uk/documents/POST-PN-0548/POST-PN-0548.pdf

Qin, W., & Brown, J. L. (2007). Public Reactions to Information About Genetically Engineered Foods: Effects of Information Formats and Male/Female Differences. *Public Understanding of Science*, *16*(4), 471–488.

Australian National University

Appendix: Covidence Data Extraction Template

Paper reviewed by

- Will Grant
- Heather Bray
- Rebekah Harms
- Joan Leach
- Rachel Ankeny

Overall relevance (On any human response to NBT or GM modification of food, in the world):

- Include
- Exclude

Paper Citation (simple author/date, eg Tizard et al. 2016)

[Text box]

DOI (if available)

[Text box]

Type of literature

- Scholarly literature
- Grey literature

Publication type

- Journal article
- Book chapter
- Government report
- Other report
- Conference paper / proceedings
- Thesis
- Other

Peer-reviewed

- Yes
- No

Study type

- Empirical (qual/quant)
- Review
- Discussion
- Editorial / Opinion

Target

- Food plants
- Food animals
- Multiple
- Weeds / Pests
- Other / General

Methodology (if empirical)

- Qualitative
- Quantitative
- Mixed methods

Description of method (if empirical)

- Survey
- Focus group
- Interviews
- Experiment
- Media study
- Other
- N/A

Sample size (if empirical, if ANZ just report ANZ numbers)

- 0-99
- 100-499
- 500-999
- (1000+ participants),

Main location of sample (If empirical)

- Australia
- New Zealand
- US
- UK
- Europe
- China
- Other

Human factor

- Attitude
- Knowledge
- Behaviour
- Risk perception
- Understanding
- Value
- Worldview

- Willingness-to-pay (WTP)
- Willingness-to-consume (WTC)
- Acceptance
- Concern
- Safety
- Familiarity
- Trust
- Labelling
- Regulation

What does this paper say about consumers' awareness and knowledge of NBTs?

[Text box]

What does the paper say about consumers' attitudes to NBTs

[Text box]

What does this paper say about consumers' risk perceptions of NBTs?

[Text box]

What does this paper say about consumers' behavioural responses to NBTs?

[Text box]

What does this paper say about factors which influence acceptance of NBTs (e.g., environmental, health, economic, regulation)?

[Text box]

Is there congruity between the research question or objectives, the research methodology and philosophical (theoretical) perspective, the methods used to collect data, the representation and analysis of data, and the interpretation of results?

- Yes
- No
- Unsure

Do the conclusions drawn in the research report flow from the analysis or interpretation of data

- Yes
- No
- Unsure

In experimental or quantitative studies, is it clear what is the 'cause' and the 'effect', and that correlation is not being interpreted as causation?

- Yes
- No
- Unsure
- N/A

In experimental or quantitative studies, were any comparisons being made between participants who were similar? (Were they comparing apples with apples)

- Yes
- No
- Unsure
- N/A

In non-empirical/opinion papers, is the source of the opinion clearly identified and has standing in the field of expertise?

- Yes
- No
- Unsure
- N/A

In non-empirical/opinion papers, is the stated position the result of an analytical process, and is there logic in the opinion expressed?

- Yes
- No
- Unsure
- N/A

How would you rate the overall quality of this paper?

- Low
- Medium
- High
- N/A

How would you rate the usefulness of this paper?

- Low
- Medium
- High

Any comments

[Text box]