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"In between hopes and fears": Exploring moral emotions and perceptions around genetically modified micro-organisms (GMMs)

Author:

Meinske Haak (4444213)

Graduation committee:

Dr. Andrea R. Gammon	(first supervisor)
Dr. G. van de Kaa	(second supervisor)
Prof. Dr. S. Roeser	(chair)

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Delft University of Technnology

Supervisors: Dr. A.R. Gammon & Dr. Geerten van de Kaa & Dr. S. Roeser (TU Delft)
Dr. L. Cornacchia & I. Schoeman Giziakis (Danone Nutricia Research)

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ACRONYMS

CBA	Cost benefit analysis
COGEM	Commission on Genetic Modification
DNA	Deoxyribonucleic acid
DPT	Dual process technology
EFSA	European Food Safety Authority
EU	European Union
GFI	Good Food Institute
GM	Genetically modified
GMO(s)	Genetically modified organism(s)
GMM(s)	Genetically modified micro-organism(s)
GMP(s)	Genetically modified plant(s)
GMA(s)	Genetically modified animal(s)
HMO(s)	Human milk oligosaccharide(s)
IPA	Interpretative phenomenological analysis
NGOs	Non-governmental organizations
OECD	Organisation for economic cooperation and development
rDNA	Recombinant deoxyribonucleic acid
US	United States
UK	United Kingdom
VSD	Value sensitive design

1 PREFACE

When we say 'Genetic Engineering', 'Genetic Modification', 'Altering of DNA'. Think about these statements for a moment. How do you feel and what do you think about these concepts?

In this research, I asked this question to people who are familiar and who are not familiar with genetic engineering. Responses varied between 'Sustainable process', 'Innovation', 'Future', 'CRISPR-Cas9' and, 'Frankenstein food', 'Demonized food', 'Ideal but tasteless food', 'Artificial', 'Oncomouse and Dolly the sheep'. As one of the respondents said, we can perceive the technology as a 'double-edged sword' that can either be positive or negative. Lots of these concepts are related to previously heated discussions which include emotions. Most likely, these emotions are built from representations of genetically modified organisms (GMOs) which are intuitively appealing. These representations tap into deeper emotions that mostly work under the radar of conscious awareness, and such representations become easy to think even if they are untrue (Blancke, 2015). In 2013, a movement to end the production of GMO products by Monsanto started by millions of people. They marched globally to protest against genetically modified organisms and roundup (see Figure 1.1). People demonstrated in several cities within the US to planned events in other regions of the world to come together to strike against GMOs. The protesters gathered, calling for more protected food supplies and creating awareness of the harmful impact of genetically modified foods. You can imagine that all sorts of emotions are at the basis of these strikes and heated discussions. All sorts of negative responses such as disgust, fear, and anger contradict the more positive emotions that, for example, scientists feel while working on technology. These emotions have to be considered to make ethically responsible decisions on genetic engineering applications. Because, for many people, the emotional responses are the starting point of these debates involving various ethical concerns.

Figure 1.1: Anti-Monsanto marchers 24 May 2014 by Chris Goodwin.

2 ABSTRACT

Solving the world food problem, health, and sustainability issues have become principal objectives of modern biotechnology. With the help of genetic engineering, the DNA of micro-organisms can be altered to produce value-added products (e.g., enzymes, vitamins, and alternative proteins) efficiently and sustainably. There has been lots of research activity about public perception and acceptance of genetic engineering in the food industry during the last decades. The EU Regulations provide significant loopholes, and companies fear strong anti-genetically modified organisms (GMO) lobby due to early scandals to notably GMO plants and animals. Until now, most research groups studied the public perception of genetically modified animals (GMAs) and genetically modified plants (GMPs). However, the public perception towards genetically modified micro-organisms (GMMs) has not been studied intensively, while valuable products are hampered. This research explores public emotions and underlying ethical concerns towards GMMs in the dairy-based industry through literature research, semi-structured expert interviews, and online questionnaires. Experts in this field hypothesize that people look differently towards specific GMO products and that consumer acceptance rises when a clear benefit is given. Techno-ethical scenarios were created to study laypeople and to verify different propositions made by experts. Roeser (2018) argues that moral emotions can play an important role in judging the ethical aspects of risky technologies. We used the theoretical approach from Roeser (2018) as a guideline to offer concrete recommendations for further study and essential elements to consider for decision-making on GMM technology. From this research, it can be concluded that the opinions, as in other debates, do not seem to be polarized. The majority of the public feels optimistic about GMM products when it gives a clear benefit. The emotions point to ethical concerns that are most important for specific types of products and consumers. The negative emotions (fear, anger, powerlessness, irritation, and disgust) and positive emotions (interest, hope, joy, happiness, and surprise) link to awareness, trustworthiness, and autonomy to be essential for GMM product acceptance.

This thesis is executed in collaboration with the world food leading company Danone Nutricia Research. Danone Nutricia Research shares the interest in GMMs and has to deal with the ethical debate of its use in dairy-based industry next to its necessity to follow the regulations.

3 EXECUTIVE SUMMARY

It is estimated that there will be nearly 10 billion people globally by 2050 (Tripathi et al., 2018). And the overall food demand is expected to increase by 50%. To meet this demand and to keep the world population healthy, food sources need to become more diverse, efficient, and sustainable (Ormandy et al., 2011; Tyagi et al., 2020). On top of this, the fortification of food with essential nutrients, vitamins, and amino acids is needed together with the delivery of tailored enzymes to achieve unique food processing capabilities (Hanlon and Sewalt, 2021). One of the current aims of modern biotechnology is to solve these demands by using genetically modified micro-organisms (GMMs) or also called genetically engineered micro-organisms (GMEs) (Mishra et al., 2013). Since GMMs is not a globally shared definition we would like to emphasize that we focus on: *products from or based of micro-organisms (bacteria, fungi, or viruses) in which the genetic material has been altered principally through recombinant DNA technology, in other words, by means that do not occur naturally* (Stemke, 2004). The world food leading company Danone Nutricia Research is currently investigating the potential of GMMs to produce value-added ingredients and make an impact on sustainability. However, this promising technique is perceived to be risky and disruptive. By implementing the technology, several concerns could be raised about the potential hazards posed by the technology, which could clash with several intrinsic values (e.g., naturalness). The altering of DNA and the massive introduction of new GMM products in the future may trigger negative emotions and rejection of the technology. As GMMs have become more refined and developed in increasing applications, society's questions about the technology have become more widespread and vocal (Belderok, 2021). Not only the researchers express their concerns, but also regulators and large segments of the public, who tend to see genetic engineering as unnatural, dangerous, or unnecessary (Chapter 1).

Policymakers have been applying cost-benefit analysis (CBA) theories to several genetic engineering applications. This method has been considered value-neutral, rational, and objective to determine if the technology is ready for deployment. On the other hand, social scientists and ethicists criticize these methods for ignoring the underlying ethical concerns (Roeser, 2018). The ethical issues of genetic engineering can be considered complex due to a variety of attitudes and understanding of the concept. The research into the public perception towards genetic engineering, applied to micro-organisms specifically, is still in its infancy. The opportunity for the dairy-based industry is there to produce lots of interesting, valuable products that can be made for various target groups. Hence, it is expected that these ethical concerns can be categorized depending on the production process, the type of organism, the type of consumer, and the particular final deliverable. It is hypothesized that, for example, less resistance or negative feelings are linked

to the modification of microbial DNA as compared to the modification of animal DNA (Stemke, 2004). In addition, the type of product (food additive or processing aid), type of consumer (patient or non-patient) may very well have a significant influence on the acceptance of the technology. Recently, next to the importance of ethical considerations, another complexity has been added to improve public acceptance potentially. Following Roeser (2018), a more responsible innovation can be reached by including emotions in decision-making processes and assessing technological risks. It is expected that public emotions are linked to important underlying ethical considerations, which lead to different judgments about the technology. Furthermore, experts and laypeople are hypothesized to have different connotations of risk, leading to a greater risk acceptance for experts.

In this study, the current public emotions and underlying concerns towards this risky technology, GMMs, are studied and evaluated. First, expert interviews and literature will provide essential information to look for by quantitative studies (questionnaire). Based on the findings obtained from this thesis research, several future research areas for the dairy-based industry and academic research are created. This research remained exploratory and therefore open-ended. The objectives of this study have been defined in collaboration with Danone Nutricia Research and translated into the following main research question:

"What are the public emotions and underlying ethical concerns towards genetically modified micro-organisms (GMMs) in dairy-based industry and how to evaluate them?"

To answer this main research question, the following (sub) research questions have been defined and relate to both normative and descriptive parts of this research:

1. What are the ethical concerns on GMM in comparison to genetically modified animals (GMAs) and genetically modified plants (GMPs)?

2. What are the public perceptions and emotions towards GMMs?

3. How do we evaluate the ethical concerns, which include perceptions and emotions?

The study's design consists of two exploratory phases with a large qualitative phase and a second shorter quantitative phase.

3.1 QUALITATIVE/EXPLORATORY PHASE

The literature was studied by content analysis to look for essential information on GMMs. The pros and cons of the technology in dairy-based industry were summarized. The importance of this technology is described together with the relevance of this research. Based on the literature study, we prepared the semi-structured video-recorded interviews. Three types of experts have been interviewed to get an overview of the scope and implications of GMMs in the dairy-based industry.

In these interviews, it came forward that experts are optimistic about the technology but also fear specific applications. In total, we interviewed nine experts related to biotechnology in a social sciences, technical or policy-making way. The results imply that a case-by-case analysis is needed to study the concerns to certain products. The particular type of organism matters to people (animal or microorganism, or plant), but it seems that it is more than that. It is also about the type of consumer who is receiving the product and its specific purpose. Apart from the product purpose, trust is an underlying factor that makes people positive or negative about the technology even though the products' benefits or risks are clear. The findings from the exploratory phase were used to develop the online questionnaire to study laypeople's perceptions.

3.2 QUANTITATIVE PHASE

An online questionnaire was developed from the outcome of the first qualitative phase of the study. 81 students from the Delft University of Technology and 90 people working within Danone Nutricia Research responded. The questionnaire consisted of five sections that touched upon different topics such as general knowledge, trust, perceived benefits and risks, demographic variables, and emotions towards specific GMM products. We developed two different survey versions. Both questionnaire versions first describe a general dairy-based product, such as yogurt, which GMMs produce in a contained environment. The following product in the questionnaire is produced in the same way, but the purpose is different for each version. In version 1, the reader is put in the position of a parent who needs to buy a GMM product where the alternative product can be considered unethical, such as baby milk. In version 2, the reader is put in a patient in need of a medical GMM product.

The results imply that the opinions are not always polarized but have combined positive and negative considerations. The emotions which were felt the most towards these GMM products were interest, hope, and fear. To respect the importance of emotions, their linked antecedents of emotions - trustworthiness, autonomy, and awareness - can help with decision-making. Dairy-based companies should use emotions to understand better public concerns and impressions, leading to dialogue, trust, and insight in values to make social acceptable innovations. Interestingly, compared to previous GMO implementations, the emotions of anger and disgust, which mostly point to the naturalness concern, were not felt the most. In both versions, the particular medical product created a higher degree of positive emotions than negative ones. The sample under study did not trust food companies as much as the experts expected. One of the main information flows seems to come from social media, which is problematic.

3.3 FUTURE STRATEGY

Based on the findings obtained from this research, I suggest that the dairy-based industry, both companies, and the public, should increase awareness of the potential of GMMs specifically. Distinctions must be made between the type of organisms and the type of consumers on a case-by-case basis. The focus should first be on products where the benefits are clear to society while acknowledging criticism and being open about the risks. People should also be given the freedom to choose between different products to transition towards GMM products. Next to autonomy and awareness, trustworthiness is an underlying factor that must not be forgotten. Dairy-based companies must work on their trust level by collaborating with independent third parties such as research institutes and universities. However, before developing a communication strategy, more research in other GMMs specific products is required, together with the differentiation between global regions. To increase the reliability of this research, a more interactive method such as focus groups can help to study better the emotions and ethical concerns of laypeople and experts.

3.4 CONTRIBUTION AND FUTURE WORK

The results from this thesis can be used by academic research to expand existing literature on emotions and underlying ethical concerns regarding GMMs. This research shows that emotions point to specific values, varying per application and group under study. The results can be used to improve further the assessment of risky technologies and the survey into important emotions and values.

The results of this study can be used for studies that investigate improvements in the acceptance of GMM products. The most triggering and felt emotions can be studied and used to explore why people are against a certain product even when the benefits are clear. A controversy towards future GMM products can possibly be avoided by acknowledging the importance of emotions.

4 INTRODUCTION

This chapter introduces the thesis topic by addressing its academic and practical relevance, research objectives, and research design. The last section of this chapter gives an overview of which information is present in which chapter.

4.1 BACKGROUND

More efficient and sustainable food production, together with the demand for superior and tailored nutrition, has pushed technological developments towards the genetic modification of organisms (GMOs). Interesting products can be made by isolation or manipulation of the genetic genome (DNA) of micro-organisms, plants, and animals. For this research, the focus is emphasized to products from genetically modified micro-organisms (GMMs). The term GMMs is not globally acknowledged; therefore, we would like to clarify what we understand with GMMs. *Products (Figure 4.1) from or based of micro-organisms (bacteria, fungi, or viruses) in which the genetic material has been altered principally through recombinant DNA technology, in other words, by means that do not occur naturally* (Stemke, 2004). The debate about GMOs - GMPs (plants), GMMs (micro-organisms), and GMAs (animals) - has been going on for years and has extended mainly in the actors' scope. However, what sparked the controversy in the food industry specifically? The risk perceptions concerning food have been explored since 2000 while the food safety concerns have already steadily increased since the 1970s (Knox, 2000). This recent attention may link to the vested interests in new food technology (genetic engineering or irradiation) from the governmental institutions and funding bodies. Until 1996, the public debate had been relatively quiet, but this changed when Monsanto shipped unlabelled genetically modified (GM) soybeans from the United States to Europe. GMO food was already criticized in general due to safety concerns, and previous food scares involving dioxin-contaminated foods from Belgium, and the cloning of Dolly the Sheep in 1997 (Beer, 2015). These events created public distrust, and the public lost confidence in governmental institutions. In response, the European Union (EU) implemented the first mandatory labeling regulations for GMO food, and from 2004, the literature on the issues with GMOs declined. However, after some silence, public controversies start to arise again (e.g., COVID-19 vaccination) (Belderok, 2021). The number of food and health products made with or from GMMs is increasing tremendously, and the development of the technique is booming (Figure 4.1). Non-technological solutions such as managing demand and reducing waste are critical, but they will most likely not be enough. To satisfy the future global food demand and keep the world population healthy, innovation will need to come from a broad range of technologies (e.g., Artificial Intelligence, robotics, and synthetic biology).

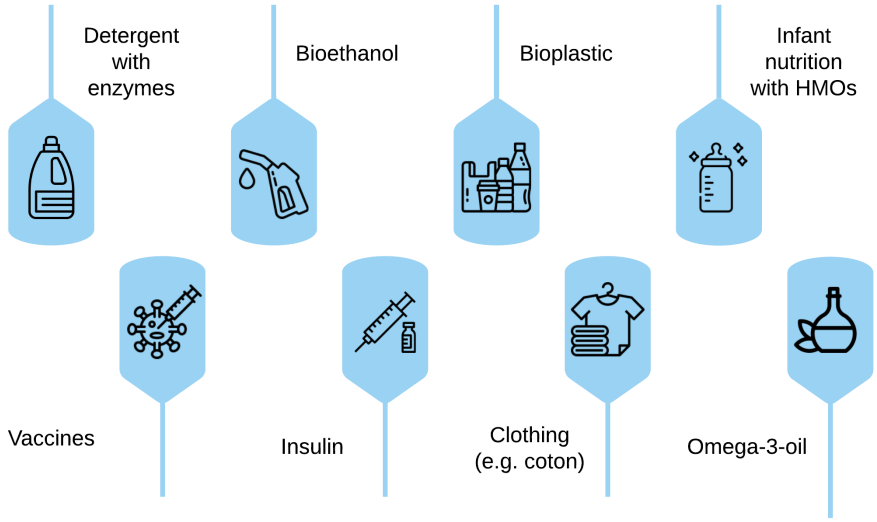


Figure 4.1: An overview of the products based on or made by genetically modified micro-organisms (GMMs). (Belderok et al., 2021)

Among the most promising techniques, genetic engineering has raised the most public controversies. Hence, people did significant research in recent years about different issues related to the topic. For example, safety assessments, theories on risk perception, and consumers' acceptance (Knox, 2000). And still, several research challenges remain to be tackled. One of these remaining challenges is understanding public perception towards the products from or based on GMMs. The risk assessments and public perceptions towards GMAs and GMPs have already been widely discussed by several research groups, which are therefore not part of the scope. However, the information retrieved from these studies functioned as a basic understanding of the public perception towards GMMs. New technologies can bring significant benefits, but they can also create novel and catastrophic costs/risks (Figure 4.2). After introducing a technology such as genetic engineering, a recurring pattern often emerges and is linked to the views of experts and laypeople (see preface). The public is first alarmed and worried about risks, while experts assure them that the chances are negligible (Roeser, 2018). Some technologies regarding sustainability happen smoothly, while others have encountered different degrees from the public. Several studies have shown that technology acceptance is the most crucial element to create a social license to operate (SLO), which can be defined as approval and ongoing acceptance by all stakeholders for technology development (Wood and Thistlethwaite, 2018). However, policymakers tend to only focus on social acceptance, where we could overlook critical ethical aspects of technological risk. Taebi et al. (2017) argues that "social acceptance studies are not capable of sufficiently capturing all the morally relevant features of risky technologies; ethical analyses do not typically include stakeholders' opinions, and they, therefore, lack the relevant empirical input for a thorough ethical evaluation." Previous studies on public perception towards GMMs do also not seem to integrate the moral issues. In this research, we therefore use a different approach, which we will introduce in Chapter 6. This approach takes stakeholders' perceptions seriously by studying emotions and values (Roeser, 2018).

Companies should learn how the public creates their opinion towards specific GMM applications and how they perceive the associated risks and fairness for responsible and successful technology implementation. The world food leading company, Danone, shares an interest in GMMs and has to deal with the ethical debate of its use in the dairy-based industry next to its necessity to follow the regulations. Danone Nutricia Research Institute currently investigates the potential of GMMs to produce value-added ingredients. The institute is the global research and innovation organization behind Danone Early Life Nutrition and Nutricia Advanced Medical Nutrition, part of Danone (Danone, 2021).

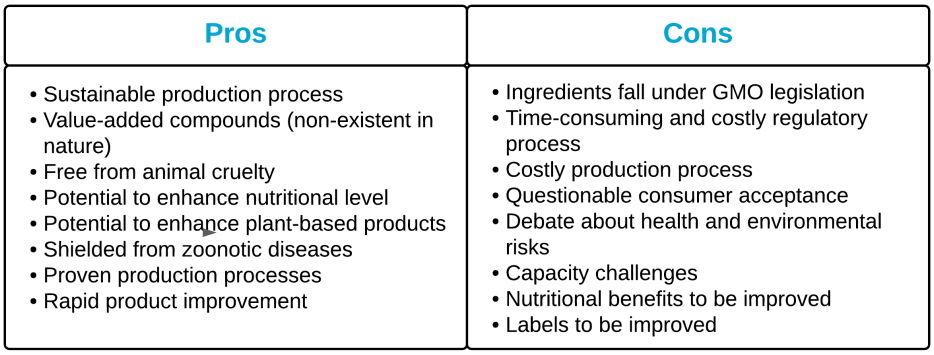


Figure 4.2: An overview of the pros and cons of using GMOs for various production processes. GMOs include GMMs, GMPs, and GMAs. (Belderok, 2021)

4.2 RESEARCH OBJECTIVE AND QUESTIONS

Research about GMMs is still in its infancy while their applications are booming. GMMs are essential for the production of value-added products and for satisfying the world food demand in the long run (Stemke, 2004). Until now, research has primarily focused on the public perception towards GMAs and GMPs in food industry. Hence, there is a knowledge gap to fill for GMMs in the dairy-based industry specifically. The main research objective of this thesis is, therefore, *to empirically study the public emotions and underlying ethical concerns towards human-health dairy-based products produced by genetically modified microbial fermentation.* The products of interest entail value-added compounds like alternative proteins and vitamins. These products are different from the ones from (1) breeding, or cloning by genetic engineering and (2) genetically engineered plant-based products that are deliberately released as opposed to contained environments (e.g., bioreactor). Firstly, the objective was to identify to what extent we should consider the ethical concerns to be different for GMMs, GMPs, and GMAs. Secondly, the aim was to research whether people show different opinions towards specific GMM products, assess them, and evaluate the research design. Lastly, the objective was to distinguish the various implications of this research and give recommendations interesting for further investigation.

The objectives of this study resulted in the following main research question:

"What are the public emotions and underlying ethical concerns towards genetically modified micro-organisms (GMMs) in dairy-based industry and how to evaluate them?"

To answer the main research question, the following (sub) research questions have been defined and relate to both normative and descriptive parts of this research:
1. What are the ethical concerns on GMM in comparison to genetically modified animals (GMAs) and genetically modified plants (GMPs)?
2. What are the public perceptions and emotions towards GMMs?
3. How do we evaluate the ethical concerns, which include perceptions and emotions?

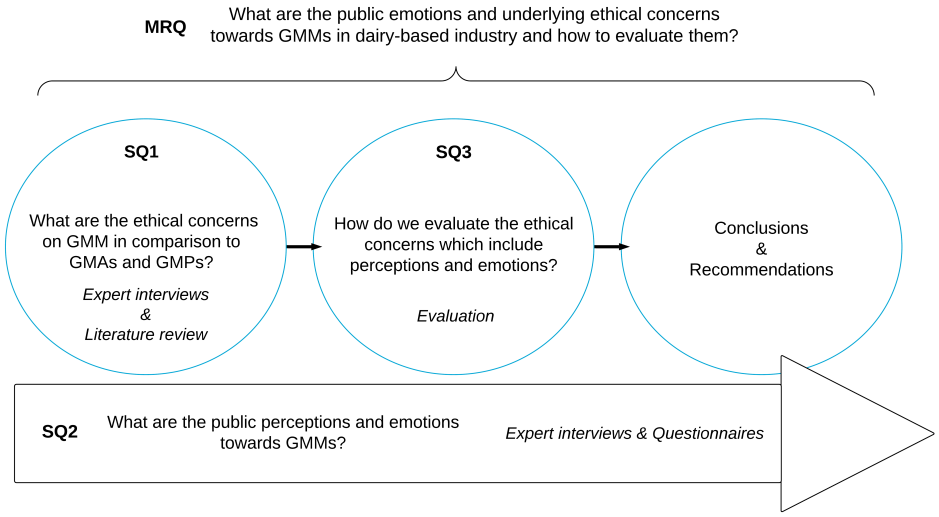


Figure 4.3: A schematic overview of the research design that represents the main research question and its underlying (sub) research questions.

4.3 RESEARCH DESIGN

This research consists of two distinct phases that follow the principles of a mixed-methods study, where a survey study is developed based on the results of the first exploratory phase. The research methods link to the (sub) research questions in a specific order (Figure 4.3). The first (sub) research question relates to the relevance of this study by exploring the public perception of genetic engineering of different organisms by extensive literature research and semi-structured interviews. The second (sub) research question relates to the analysis of emotions and moral issues towards the technological risk of GMMs specifically. The last (sub) research question focuses on evaluating the results and the applied research methods. The focus of the research has remained exploratory, in which we will clarify the exact nature of the problem.

4.3.1 Two phased research

As a research methodology, qualitative research methods, like semi-structured interviews and literature studies, infuse added advantages to the exploratory capability of this study. We have used semi-structured video-recorded interviews to determine which concepts were more important than others for the next quantitative stage. Chapter 7 summarizes the results from the interviews by categories, themes, and sub-themes and their connection by a neutral voice. However, the discussion section evaluates the interpretations on these category connections by previous studies published in relevant scientific journals. The results from this qualitative part (literature study (Chapter 5), theoretical framework (Chapter 6) and the findings from the expert interviews (Chapter 7)) have been used as input for the quantitative part. An online questionnaire helped to study laypeople's emotions towards GMMs and specific applications in the dairy-based industry. The questionnaire consisted of a big quantitative part and a minor qualitative part with open questions to allow respondents to include more information on emotions, feelings, attitudes, and understanding of the topic of interest. The respondents were not given any information on the technology before participation. In this way, it would be possible to study their gut feelings.

4.4 THESIS OUTLINE

The following chapter (Chapter 5) discusses the relevance of GMMs and how this technology is developing. It discusses the technologies' advantages and disadvantages, and we will compare literature on genetically modified animals (GMAs) and genetically modified plants (GMPs). Chapter 6 discusses the literature on emotions and risky technologies concerning public acceptance and ethical acceptability (Taebi, 2017). This chapter stresses the importance of the integration of emotions in technology development for successful deployment. The results of the qualitative part of this research, expert interviews, will be discussed in Chapter 7 to answer the first (sub) research question. The outcome of the expert interviews has also been used to design the questionnaire. The information on the survey construction can be found in Chapter 8, and the data have been analyzed to answer the second (sub) research question. This study finalizes with a discussion of the results Chapter 9 to evaluate the approach and outcome, a conclusion in Chapter 10, and some recommendations for further research inside and outside Danone Nutricia Research (Chapter 11).

5 GENETICALLY MODIFIED MICRO-ORGANISMS

The beginning of this chapter explains the literature study approach. The findings of the literature study helped to have more information on the relevance, advantages, and disadvantages of GMMs specifically. This chapter also summarizes the main findings on the public perception towards various applications of genetic engineering. The results of this chapter helped to guide the expert interviews in this study (Chapter 7) and the development of the questionnaire (Chapter 8).

5.1 LITERATURE STUDY APPROACH

For the literature review, a qualitative content analysis method was used (Dürnberger, 2019; Frewer et al., 2013). By the qualitative content analysis of Mayring and Kuckartz (2003 and 2012), the literature was summarized and ordered systematically by gradually processing the data via a pre-specified system of categories (Mayring and Fenzl, 2014; Kuckartz, 2009; Dürnberger, 2019). In total, 45 papers or books published between 1993 and 2021 were used for this qualitative content analysis. The most relevant subtopics were derived and coded to extract relevant information from each paper (Table 5.1). More information on the coded literature can be found in Section B.1 where the emphasis has been put on country, purpose, methodology, findings, and gaps found by database searching ('Scopus' and 'SciFinder'). Before the start of the literature review, the general topic has been already defined by Danone Nutricia Research (Utrecht, NL): "*the ethical aspect of usage of genetically engineered ingredients*". Hence, the searching process into interesting articles on genetic engineering was straightforward, leading to valuable literature sources. For the basic understanding of genetic engineering, the book *'In Comprehensive Biotechnology'* was used to give a general overview of the basic concepts (Pyne et al., 2019). *'The GMO Handbook'* was consulted for information on genetic engineering of specific organisms (Stemke, 2004). The literature on the application of genetic engineering in the food industry was quite extensive, where the articles mostly focused on agriculture and crops. However, the information on the ethical concerns of the technique used upon micro-organisms was limited. Especially, focusing on specific value-added food products for therapeutic purposes can be considered extremely novel and complex from an ethical point of view. Furthermore, the books *'The Ethics of Technological Risk'* (Asveld and Roeser, 2009) and *'Risk, Technology, and Moral Emotions'* (Roeser, 2018) helped to narrow the ethical discussion point towards risk ethics and emotions. Understanding how people perceive technical risks from an ethical point of view is essential for acceptance. First, basic literature on risk ethics was searched by using keywords as 'risk ethics' and 'ethics of risk' in the research databases, 'SciFinder' or 'Scopus'.

By narrowing down the scope towards genetic engineering, fewer articles were found on ethical considerations towards this technology. On the other hand, a broad range of topics was available in the literature on the standard way to judge the acceptability of risk (Aguilera et al., 2013; Bauer-Panskus et al., 2020; Rajan and Letourneau, 2012). Risks have been calculated and evaluated by cost-benefit analysis (CBA), whereas legitimate moral considerations also seem to be relevant. A more precise search into the risk ethics of genetic engineering was done by using the keywords 'risk ethics' and 'genetic engineering or genetic modification' in 'Google Scholar'. Finally, 'Sci Finder' made it possible to consider the following essential concepts: public acceptance and perception. Three exciting articles (Frewer and Shepherd, 1995; Taebi, 2017; Frewer et al., 1995), together with all the other works, made it possible to narrow the topic for the literature study. While performing the literature research, the articles and books from Dr. Lynn J. Frewer and Prof. S. Roeser were found to be most valuable for this research.

Table 5.1: Codes and number of articles that are linked to the specific subtopics discussed in this literature review (Section B.1).

Code	Definition	Number of articles/books
G	Genetic engineering technique and application	1
E	Ethics in general	4
Ex	Extrinsic arguments	3
In	Intrinsic arguments	2
ET	Ethical theories	2
RE	Risk ethics	12
RA	Risk assessment	4
N	Nature as concept	3
TC	Type of public	10
TO	Type of organism	3
TP	Type of product	1
CP	Consumer perception	18
L	Labelling	8
CI	Company image	7
T	Trust	9
R	Regulations	6
CS	Communication strategies	5

Selection criteria

Specific selection criteria have been used and were based on Danone Nutricia Research's standards considering the dairy-based industry and value-added products to enhance the health of humanity. The quality of the works on general information assessed by the number of citations, reviews, and the author's reputation. However, once little research activity was available on the more complex topics, the abstract and selection criteria helped to distinguish the best literature from the least. The articles were selected by industry, type of product, public, and ethical focus. Specifically, the food industry, value-added/health products, general public/consumers, and risk ethics/moral perspectives. To maintain a literature database, the reference management tool 'Mendeley' was applied.

5.2 WHY GENETICALLY MODIFIED MICRO-ORGANISMS?

In 1944, the universal genetic material (deoxyribonucleic acid: DNA) was discovered together with its molecular structure a decade later (Pyne et al., 2019). This was the official start of the research into DNA and its opportunities. Several researcher groups developed genetic engineering techniques to artificially modify the DNA of organisms (Figure 5.1). It has the potential to reduce waste and resource requirements while at the same time offering great success in yield, quality, and cost reduction (Hanlon and Sewalt, 2021). Genetic engineering has contributed to significant improvements in various industries such as the pharmaceutical (vaccines, hormones, etc.) and food industry (baking, brewing, etc.) (Stemke, 2004). In agriculture, resistance against herbicides or insects arose. For this research, emphasis has been put on the dairy-based industry with products such as cheese and yogurts but also the cost-effective fortification of food by genetic engineering (Ellahi, 1994; Hanlon and Sewalt, 2021). For example, nutrients, vitamins, and amino acids, and the delivery of specialized enzymes to accomplish specific food processing capabilities.

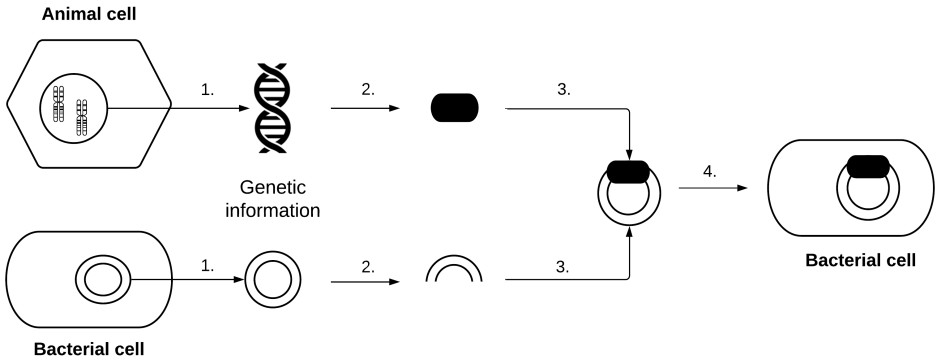


Figure 5.1: A basic process scheme depicting the genetic engineering technique including replication and expression of recombinant DNA according to the central dogma of molecular biology (Pyne et al., 2019). 1. Extraction of cellular DNA. 2. splicing DNA 3. insertion animal DNA into bacterial DNA 4. introduction to host strain. * cells from: animals, micro-organisms and plants.

5.3 HOW DOES GENETIC ENGINEERING WORK?

The most common mechanism for creating GMMs to produce food substances is through in vitro nucleic acid techniques (Hanlon and Sewalt, 2021). With the help of recombinant DNA (rDNA), specific genes can be inserted into a selected, robust, and safe micro-organism (Skovgaard, 2005). In this way, the performance of the micro-organism can be optimized or a new functionality can be added to that micro-organism. Next to the direct manipulation of genes within species, genes can also be transferred from one species to another (Jones, 1996) (Figure 5.1). Using gene-editing, desired products can be produced whereas it is not naturally produced by the organism (Gregg, 2017). Gene-editing technologies such as CRISPR/-

Cas9 (Nobel Prize in Chemistry for gene-editing technology 2020) are testing the boundaries of genetic alteration. They have the potential to transform a variety of sectors (Belderok, 2021; Dürnberger, 2019; Tyagi et al., 2020). CRISPR/Cas9 has revolutionized molecular genetics by allowing targeted genetic modification in the whole genome with far greater efficiency without the need for foreign DNA introduction into the genome. As a result, current GMMs can be created in a timely and exact manner. These simple alterations in the genome do not result in additional risk.

5.4 PUBLIC DEBATE

The development of genetic engineering and its likely consequences raises issues beyond the scientific level and opens up a public debate (Frewer and Shepherd, 1995). As Lassen et al. (2006) stated, "Until recently the main limits to genetic engineering were technical: what is *possible* to do. Now scientists are faced with ethical limits as well: what is *acceptable* to do". Ethics can be defined by a set of standards regulating the behavior of a specific group to distinguish what is morally acceptable in pursuit of their aims from what is not (Frewer and Shepherd, 1995). The ethical issues of genetic engineering can be considered complex due to a variety of attitudes and understanding of the concept. Frewer et al. (1995) addressed that the ethical problems are linked within the nature of the application of the technology. It holds that not all moral arguments are equal, and their conclusions should be based on ethical principles, reasoning, and consensus (Stemke, 2004). Genetic engineering researchers and end-users try to inform about potential consequences and usually do not identify the technique as intrinsically wrong. Hence, a public controversy has been generated where normative concepts of nature are debated between different stakeholders involved (Dürnberger, 2019). Many social and behavioral scientists tend to focus on public concerns towards the genetic engineering of animals and plants. It turns out that research on **genetically modified micro-organisms** is still in its infancy. Especially emotional studies are lacking, which could help evaluate the risky technology for decision-making, as addressed in Chapter 6.

5.5 ADVANTAGES AND DISADVANTAGES

In the paragraphs above, some advantages of GMMs have already been addressed. All benefits can be subdivided into three parts. Firstly, GMMs respond to consumer demand for sustainable food, free from animal cruelty and potentially with better nutritional levels (Belderok, 2021). Secondly, GMMs have an efficient and controlled process shielded from volume and price volatility (independent of climate/ economic/political factors). And lastly, GMMs are the enhancers of plant-based alternatives and enablers of new technologies. The disadvantages, however, remain to be less precise. Three core disadvantages can be discussed that hamper successful market deployment. First of all, the main drawback is the risks and how they are perceived, resulting in companies and research institutes being

more careful with GMM products. Secondly, technology development costs are high due to scale-up requirements to bring prices down and a time-consuming regulatory approval process. The costs of technology adoption occur in one stage of the chain, while the benefits are primarily perceived in a later stage (Mora et al., 2012). Lastly, the GMMs that are not processing aids (definition Section 5.8.1) currently fall under GMO legislation and have not been authorized in Europe yet.

5.6 RISKS

The identification, characterization, and handling of risk(s) from genetic engineering follow a structured approach by three interconnected elements: risk assessment, risk management, and risk communication (EFSA, 2011b). The risk assessment is a scientific exercise, and data must be available for qualitative and quantitative risk estimates. The European Food Safety Authority (EFSA) provides GMO risk assessment guidelines which differ per type of organism: animal (GMA) (EFSA, 2013), plant (GMP) (EFSA, 2011a) or micro-organism (GMM) (EFSA, 2011b). Focusing on micro-organisms, the type of risk assessment differs per final product and its specific DNA manipulation. The risk assessment determines the certain risk category of the GMM and its product(s), which can be divided into four categories (Section B.2). The lowest risk category (group 1) relates to the biological agent that is unlikely to cause human disease in contrast to the highest risk category (group 4) (European Union, 2021). The four levels have been constructed based on different factors such as the spread to the environment and effective treatment available. Depending on these factors, severe human disease can arise, and serious hazards can be brought to workers. The risk assessment depends on the category for which clear guidelines are set. These categories correspond to the environment in which the organism is present; contained environment or deliberate release. However, institutions (e.g., The Netherlands Commission on Genetic Modification (COGEM)) still have comments for improvements to be made on these risk assessment guidelines (Cgm, 2006). Hence, a consensus on the risk assessment of GMOs is still lacking. Up until now, risk assessments have already been executed for quantifying and describing the risks associated with genetic engineering (Rajan and Letourneau, 2012). The regulation of GMO products has been up to key government agencies, but the identification of the safety issues has been the responsibility of the scientific community (Stemke, 2004). For this reason, many research papers are available on the potential risks of GMOs but have been criticized for neglecting the social aspects of risk, and their lack of consensus (Frewer et al., 1995).

The possible risks related to GMMs have been studied, and multiple hypotheses have been made for humans and the environment. For example, the hypothesis is that foods from GMMs can trigger allergic reactions because they may contain genes from an allergen (food that prompts an allergic reaction). Some other researchers believe that eating GMM products can cause cancer-related diseases due to introducing new genes into the body. Another growing global concern relates to antibacterial resistance (Hanlon and Sewalt, 2021). Antibiotic resistance genes are the most widely used selectable markers for general cloning. These

genes can make the GMMs resistant to certain antibiotics, which could pass on to humans. As a result, the ability of people to defend against illness could be affected. However, it is believed to be unlikely that the genes in food can transfer to human body cells or bacteria in the gut. The GMM product or its alike could also lead to potential human toxicity and must be determined by a series of defined toxicity tests (Stemke, 2004). In a paper by Scully (2003): *"Relative to being injured in a car accident, the risks of consuming GMO food were low to most respondents"* (Scully, 2003). The other risk concerns relate to the environment. In comparison to GMPs, there have been relatively few GMMs released directly into the environment. Only about 1% of intentional GMOs released were bacterial, 0.3% were viral, and 0.2% were fungal (Stemke, 2004). The environmental risks include 'outcrossing', where certain GMM creatures mix with conventional types from nature. Risk assessors must study the ability to exchange DNA with other micro-organisms in an uncontrolled environment to determine the construct's stability. For many of these risks, there is no clear evidence. But, at the same time, evidence of no harm is not the same as proof of safety. And the public is concerned about them. So, to reach conclusions, more research is needed on the risks part and its assessment. In total, several factors need to be taken into account when considering the potential of GMM food safety, including (1) that the GMM is nonpathogenic; (2) whether it will colonize the human gut; (3) the possibility that the GMM will transfer its DNA to indigenous gut flora; (4) that the products produced from the GMM are safe; (5) that the vector components have an approved safe origin; (6) that genetic regulatory elements are safe to use; and (7) that specific foreign genes used in the GMM are safe (16) (Stemke, 2004). Genetic engineering also has a more socio-economic impact next to the environmental, animal, and human health risks (Garcia-Yi et al., 2014). For example, the technology impacts the current farm-level, current jobs, and current production processes. Another example is the need for different regulations that could affect multiple existing product lines and the risks along the supply chain.

5.7 DAIRY-BASED INDUSTRY AND LARGE-SCALE FERMENTATION

For this thesis, the focus has been put on large-scale fermentation. Fermentation is the production of food substances using micro-organisms, which is the general process through which a micro-organism converts an energy source into other substances (Hanlon and Sewalt, 2021). The Organisation for Economic Co-operation and Development (OECD) council has laid out several principles to minimize general risk from GMMs used for large-scale industrial purposes. These principles reduce the potential risks involved, which are discussed above. The micro-organisms must comply with the following essential traits. The GMM must be non-pathogenic and must not harbor known viruses; the GMM must be used safely for industrial purposes and must be unable to grow outside its industrial settings. Therefore the large-scale fermentation process mainly occurs in big reactors with the related control system. Think of fermenters or centrifuge bottles that form the primary containment barriers used to prevent the dispersal of micro-organisms

(Stemke, 2004). Hence, the production process with GMMs usually happens in a contained environment as opposed to deliberate release. Deliberate release means the intentional release of GMO material into the environment (e.g., GMPs).

5.8 ETHICAL CONCERNS

The public has a significant impact on the commercialization of ingredients from genetic engineering (Miles et al., 2005). For GMMs to be applied in the long term, laypeople must be considered next to its experts. Therefore, it is of utmost importance to understand their perception towards GMMs by assessing and evaluating the moral issues and emotions involving extrinsic and intrinsic arguments. In moral reasoning, intrinsic ideas are distinguished from extrinsic arguments by the nature of the technology versus its application. These arguments are interrelated and should not be discussed as single elements. Specific ethical theories (e.g., deontology) can provide this link, and these considerations can be found in Chapter 6. The benefits and risks can modify the consumer perception and attitudes presented (Knox, 2000). The absence of any potential use of a particular GMO product is enough for rejection. Still, when consumers perceive an individual benefit, they are less likely to have safety concerns (Savadori et al., 2004) (Miles et al., 2005). However, it remains to be unclear to which extent the perceived benefits 'outweigh' the certain risks (Frewer et al., 2014). Multiple research groups have evaluated perceived threats, but a large proportion of people do not know the technology itself neither its possible consequences (Hunt and Frewer, 2001; Scully, 2003). In the end, the public perceptions of risks and benefits vary depending on the type of risk, level of understanding, and availability of information about the risk (Frewer et al., 1995). The use of GMMs have become more valuable and developed in increasing applications. To avoid a controversy such as towards other GMOs (e.g., crops, animals), the social acceptance of GMMs and their technological risks is necessary (Stemke, 2004). So, next to proven safety and success records, the public perceptions on the risks should be considered. However, many decision-makers perceive the public opposition as an obstacle that should be overcome. Marketing methods have been proposed to maximize the likelihood of a successful introduction by investigating the people's attitudes (Taebi, 2017). Instead, we should focus on why the technology of interest could not be accepted in the first place. Hence, the conjunction of the ethics of technological risk and social acceptance is argued to be relevant involving philosophical, ethical considerations.

"Social acceptance refers to the fact that new technology is accepted - or merely tolerated - by a community. Ethical acceptability refers to a reflection on a new technology that takes into account the moral issues that emerge from its introduction." (Taebi, 2017)

Both concepts have been studied separately for many GMO applications in the food industry (Stemke, 2004; Frewer and Shepherd, 1995; Straughan, 1990). However, research into the ethical acceptability of **value-added products from microbial fermentations (closed environments)** specifically is lacking.

5.8.1 Type of product

The products from GMMs can be categorized as food additive or processing aid (Deckers et al., 2020). A food additive is intentionally being added to food to exert a technological function within the food and requires an European authorization assessed by the European Food Safety Agency (EFSA). Think of recombinant proteins or vitamins, which are directly consumed afterwards (Angel and Alberto, 2012). In contrast, processing aid is material that exerts a technological function during the food processing, but not in the final food itself and is regulated at national levels in member states of the European Union (EU). As an example, food enzymes (lactase to reduce lactose content in foods) can be considered as processing aids, which are used for the production of a consumable good. Several research groups stated that the perception on products by genetic engineering for pharmaceutical/medical industry was more positive than for the food industry. However, it turns out that this view is not always consistent as a study in Italy reported that participants were not willing to buy GMA derived nutritionally enhance food products (Miles et al., 2005). Furthermore, Saba et al. (1998) found that British people associate pharmaceutical development with negative constructs while Italians take a more positive position (Saba et al., 1998). So, it seems that there is still some uncertainty about the public understanding and perception towards specific types of products and its applications. Future research is required for enlightenment, especially considering dairy-based products with a therapeutic purpose. A few food additives are nowadays produced by GMMs, including chymosin, pectinases, and aspartame (Stemke, 2004). However, there are proposals to develop several other GMM foods or GMM-derived food products. Especially value-added food products by vitamins and other compounds to enhance human-health. For example, microbial produced trypsin and chymosin are available as alternatives to harvesting trypsin or rennet from animal sources such as pigs and cows (Hanlon and Sewalt, 2021). As said before, GMMs deliver multiple benefits by not only replacing animal-based production methods, but also potentially offering a more sustainable production. Hanlon et al. (2021) say that the claims about sustainability relate to reduced need for land and decreasing amounts of waste from production. Especially, the GMM products that could give an extra benefit over the natural product seem to be highly valued. These food ingredients include vitamins, amino acids, functional proteins (e.g., texturants), nutritional proteins, oligosaccharides, flavors, and sweeteners. Next to the food substances, GMMs could also be incorporated as intact organisms into foods such as yogurt. This use falls outside of the scope of this research. For this project, GMM material is not present in the final product. We distinguish three final dairy-based products with different purposes:

- **To copy a natural product.**
  EXAMPLE: An animal-free yogurt that contains milk protein produced by GMMs.
- **To produce a medical health product.**
  EXAMPLE: A value-added compound (minerals, vitamins, amino-acid, oligosaccharides, etc.), which does not necessarily exist in nature, is produced by GMMs and can be added to various dairy-based products.

- **To copy a natural product where the alternative is unethical.**
  EXAMPLE: Compounds such as human milk oligosaccharides (HMOs) because the natural alternative can be judged to be unethical. The natural alternative in this case is human breast milk, which is not a commodity, and is understood by Danone Nutricia Research as a substance that should not be made into a commodity (Fentiman, 2010).

5.8.2 Type of consumer

The consumer attitudes towards genetic engineering have been observed and explained by hypothetical models and supplementary qualitative research (Verdurme and Viaene, 2003; Scully, 2003; Zhang et al., 2018) (Figure B.2, Figure B.3 and Figure B.1). The question remains whether the public is more likely to reject or be more in favor of GMO food products as they become more aware of the issues and the technology itself (Ellahi, 1996). Next to the level of understanding, the socio-demographic differences also drive the concerns towards genetic engineering. The relationships between socio-demographic variables and food preferences have been studied, but little is known with regards to GMMs specifically (Scully, 2003). In the article of Frewer et al. (2013), it was found that the ethical concerns towards GMO food had increased with time and independent of region. On the other hand, segmentation of the population was important for the acceptance level. As a result, the United States (US) is relatively more approving of genetic engineering than, for example, Europe (Miles et al., 2005). This research focuses on European regulations and people who live in the Netherlands. Next to the impact of segmentation, previous research has indicated that public attitudes can dramatically change when the application is tied to a specific goal or benefit even if those applications are seen as risky (Frewer et al., 1995). An example of this is the greater acceptance when using genetic engineering to cure patients (Stemke, 2004). An explanation for this can be linked to the low number of individuals affected or differences between the risk-benefit trade-off. To elaborate on the 'risk' position, people requiring GMO vaccines or medicines may have a worse situation than non-patients consuming GMO food. Hence, the perceived risks are seen as more acceptable in a medical context. Hunt et al. (2001) and Scully et al. (2003) suggested that the younger public have a generally more tolerant attitude to genetic engineering and are most responsive to risk information. On the contrary, general food studies found that age does not influence the public perception (Miles et al., 2005). However, older people seem to be more health-conscious and interested in high-quality products. As a result, integrating the socio-economic status and cultural context makes the perception analysis complex but rather essential. In literature, experts were found to accept genetic engineering more than the general public (Bauer-Panskus et al., 2020). However, it is necessary to address that the private views of scientists and industrialists have been largely ignored in previous studies. The focus of prior social studies has been predominantly put on the general public. For this thesis, the opinions of experts in this field were also considered by semi-structured interviews in Chapter 7 (Knox, 2000). A comparison with the general public has been made by using the results of the second stage, the online questionnaire.

5.8.3 Type of organism

Another critical factor is that the literature on the current ethical concerns mainly focuses on GM animals (GMAs) and GM plants (GMPs). The following chapter, Chapter 6, summarizes typical ethical concerns and ethical theories regarding genetic engineering. The problems are not solely focused on the complete application of the technology but rather on specific applications (Frewer and Shepherd, 1995). As an example, the transfer between organisms of the same type was not seen as less risky than transfer between different organisms (Stemke, 2004; Frewer et al., 1995). The information from all organisms has been used as core information for the expert interviews on GMMs specifically. The scheme in Figure 6.1 can therefore be supplemented or narrowed down depending on the interview results. This result relates to the first (sub) research question: How should the ethical concerns on GMMs differ from GMAs and GMPs? Different experts have been interviewed to assess their knowledge on the current public risk perceptions, issues, and concerns towards GMOs by diversifying the type of organism.

5.9 REGULATIONS AND LABELLING

European regulatory agencies review the safety of GMMs when evaluating food substances produced using GMMs to ensure that both the micro-organism and the resulting food substance are safe. The interpretation of the regulatory requirements for safety and labeling requirements of GMM food substances can appear daunting (Miles et al., 2005). Our focus, however, is the food substances that are not considered 'GMO' under most regulatory frameworks (Figure 5.2). Food substances or food with no detectable DNA do not need to be labeled 'GMO'. Therefore, GMM-produced food substances undergo significant refinement/purification steps after fermentation. In most cases, these steps remove all traces of DNA from the GMM in the finished food substance. However, unavoidable traces of GMOs may be present, and the potential of GMO-containing products is enormous. The EU regulations were perceived to be inadequate, and a desire for accountable regulatory structures arose (e.g., EFSA). It seems that these regulations fail to protect consumer transparency while preventing innovation (Belderok, 2021). In their recently published study on New Genomic Techniques, the European Commission acknowledges the ineffectiveness of current regulations and the need for a revision to deliver on the EU's 'European Green Deal' and 'Farm to Fork Strategy'. The requirements for legislation were examined to be more significant for the food industry in comparison to the pharmaceutical industry and vary according to the type of organism manipulated (Frewer and Shepherd, 1995). Society identified a need to ensure tracking of GMOs and their products (Frewer et al., 2014). All participants (from three different European countries) in Miles et al. (2005) believed that GMO products should be labeled. On top of this, the consumers would like all products to be labeled, even when there is no GM material present in the final product. Nowadays, EU regulations allow 0.9 percent of GM material to be present in food through accidental contamination because 1 percent was seen as too high by consumers. Over 95 percent of the sample in Miles et al. (2005) stated to check the food labels either all the time or sometimes. The labeling is known to increase

acceptance of the technology due to increased personal control over the potential hazard. Accurate labeling allows for monitoring of unintended effects, after which recall of products is possible. On the other hand, the labeling does not address the ethical or environmental concerns of the public (Frewer et al., 1995). Plus, labeling will have little impact without a public understanding of what the labels mean. These label unclarities again stress the clear need for effective neutral language to facilitate a general understanding of the GM technology (Frewer et al., 1996).

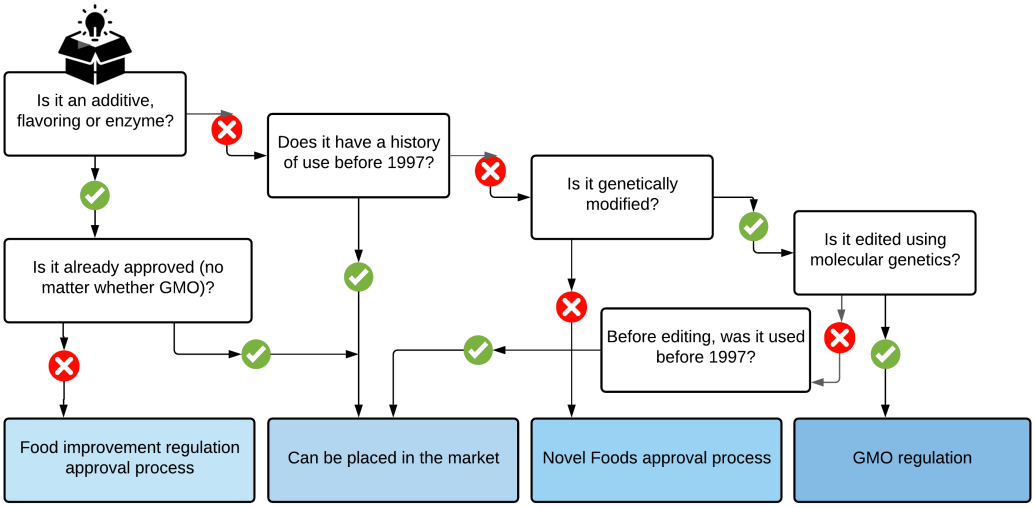


Figure 5.2: A decision tree for regulations in the European Union (EU) for GMO products (Belderok et al., 2021).

5.10 TRUST

Focusing on the public or stakeholder perception, trust is an essential element that should be considered. Trust in institutions or individuals has been found to potentially influence the public's opinion (Frewer et al., 2014). However, a low trust estimate is not necessarily linked to an unfavorable view of a particular organization (Hunt and Frewer, 2001). Hence, the knowledge estimate needs to be taken into account to explain the public trust and perception more thoroughly. Transparency is required to build trust by addressing the shared concerns (animal welfare, human health, and risk) and will be determined by socio-cultural and historical contexts. For the use of genetic engineering in Europe, it was found that research institutes and the media were more trusted as compared to political organizations and the industry, which are considered to prefer profit over and above safety (Miles et al., 2005; Frewer et al., 1995; Hunt and Frewer, 2001). Additionally, multi-group stakeholder consensus shows more credibility than information from a single source. So far, little is known about people's confidence in small or big food companies that work with GMMs. However, one could hypothesize that this is linked to the risk perception per specific application. Credibility and trust are critical factors in the effectiveness of communication strategies, whereas multiple actors can influence the company image (e.g., company, government, media,

or public) (Hunt and Frewer, 2001). The media is found to influence significantly a companies' image, which may differ per country (Frewer et al., 1995). Danone Nutricia Research and big dairy-based companies specifically built their company image by stressing the 'naturalness' of their products and processes. These focus points contradict novel small-technology companies, which are now built from genetic engineering at the start. As a result, the company size and particular core message may result in different acceptance levels of GMMs.

5.11 INTRINSIC ARGUMENTS

The normative concepts addressed in the sections before predominantly consider extrinsic values that have more to do with the consequences of the technique. However, objections to genetic engineering also seem to depend on the nature of the application, rather than being focused on the development of the technology per se (Frewer and Shepherd, 1995). Criticisms about the risks to human health and the environment could be met by taking steps to reduce its effect. However, the intrinsic arguments considering 'nature' strike more at a fundamental level regardless of the good and bad effects. The concept 'natural' is highly valued but genetic engineering is stigmatized as 'unnatural' (Scully, 2003). The technique does not follow the natural order, which is implied as good (Dürnberger, 2019). Statements as 'tampering with nature" or 'playing God' consider that we can make up living things by genetic engineering. Different interpretations on 'nature' are taken nowadays, and the emerging concepts are more diverse than the familiar reductionist breakdown of the debate suggests. Consequently, the following questions arise: What is 'nature'?, What are we to understand by concepts of 'nature'? Are these concepts vital to backdrop the controversy? These questions have already been extensively discussed in the literature but should not be forgotten. In addition to this, the debate on GMMs specifically and 'nature' is still left to be discovered. The weight of intrinsic/extrinsic arguments is likely to differ between countries. Saba et al. (1998) found that the general concept 'tampering with nature' takes the focus of objection in Italy and the United Kingdom (UK). In contradiction, the extrinsic arguments only seem to be a significant concern in the UK. These intrinsic/extrinsic differences between European countries are interesting to be examined and discussed but are not part of the scope of this research project. We focus on the more profound understanding of the public stake in the genetic engineering debate, and therefore emotions have to be considered (Asveld and Roeser, 2009). Methods such as described in Figure B.3 involve the moral issues where emotions can bring extra light to the total analysis. Roeser (2018) argues that moral sentiments can play an important role in judging ethical aspects of technological risks, such as justice, fairness, and autonomy. For the latter, Roeser's theoretical approach may well be used to offer concrete recommendations for decision-making about GMMs. Before this, the emotions should first be examined, after which the underlying ethical concerns can be evaluated.

5.11.1 Emotions

For a more profound understanding of the public stake in the GMMs debate, emotions have to be considered (Asveld and Roeser, 2009). Feelings can point to the underlying ethical concerns towards a disruptive technology. These ethical concerns may well be forgotten when emotions are not considered. Several research groups already tried to involve the moral issues where emotions can bring extra light to the total analysis (Taebi, 2017; Zhang et al., 2018) (Figure B.3). Asveld and Roeser (2009) argue that moral emotions can play an important role in judging ethical aspects of technological risks, such as justice, fairness, and autonomy. For the latter, new research is required since there is limited to no literature on the moral emotions towards GMMs. Eventually, several issues that current studies on genetic engineering and social acceptance do not consider can be identified.

5.12 DO NOTHING PRINCIPLE

The public may not accept GMO products, and this is something to take into account. The potential hazards of genetic engineering would be argued so severely that society should not attempt them. These thoughts would hamper technology deployment and development as a whole, leading to the 'do nothing principle' (Stemke, 2004). This concept relates to the precautionary principle: *when faced with uncertainty and potential risk from technology, politicians may act to prohibit the technology in the absence of scientific proof of the hazards' nature* (Stemke, 2004; Ryland, 2001). However, one can argue that apparent solutions may be neglected by ignoring the technique, such as the decrease in pollution, an improvement in food production, or possible medicines for patients. Other possible negative consequences when moving away from GMMs and GMM products are higher production costs, higher carbon footprint impact, other environmental impacts, impact on efficiency, impact on innovation, modification of the European industry's production processes, and competitiveness of European industry will be at stake. Scientists often differ in their views on whether there are real risks of adverse effects on health and the environment by GMO applications (Myhr, 2010). As a result, different policy outcomes arise and can be evaluated.

5.13 CONCLUSION

The public may accept a certain technological risk if certain benefits outweigh the risks. However, who actually benefits from this event? Which emotions play a role? And, is this also ethically acceptable? To answer these questions, the current knowledge from the extensive structured literature review required to be expanded because of the limited information on the perception towards GMMs and GMM products for dairy-based industry. As a result, an overview of the most important ethical concerns and emotions towards GMMs have been gained by the expert interviews (Chapter 7) and online survey (Chapter 8). The emotions, which possibly link to the important ethical concerns, were studied by an online questionnaire to answer the second (sub) research question. Lastly, evaluative judgments

have been made to avoid statements of what is the case (as we do with descriptive claims), but rather, what should be the case and how the study of emotions can be made better.

6 THEORETICAL FRAMEWORK

This chapter discusses dominant pitfalls and approaches to decision-making about risky technologies, such as genetic engineering (Roeser, 2018). Roeser (2018) developed a theoretical framework called 'affectual intuitionism' that combines ethical intuitionism with a cognitive theory of emotions. In this chapter we describe the relevance of this framework, especially because of the role of emotions, to GMO research and public attitudes.

6.1 PITFALLS AND APPROACHES

Roeser (2018) has reviewed three dominant pitfalls and approaches: technocratic, populist, and participatory. All methods neglect emotions and regard the emotions as irrational, which leads to the understanding that there is a dichotomy between reason and emotion. These three approaches are perceived to be inadequate since these emotions could be a source of moral reflection and deliberation to avoid common pitfalls. Pitfalls where the public is seen as supposedly emotional and poorly informed and hence incapable of engaging in a rational debate based on objectives (Roeser, 2018). Another approach, 'Affectual Intuitionism', has been proposed by Roeser (2018) to take emotions seriously. This approach builds on the participatory approach by integrating emotions.

6.1.1 Technocracy approach

The technocracy approach is widely used to create public acceptance towards genetic engineering for various applications. Social scientists, on the other hand, criticize these methods for ignoring the more ethical considerations. The function of probabilities and consequences is not entirely sufficient to judge whether a risk is morally acceptable or not. Emphasis should, therefore, also be put on the moral values that come with the technology development and deployment (Asveld and Roeser, 2009).

6.1.2 Populism approach

The populism approach arose where policymakers accept the emotions of the public and prohibit the technology in question. No public support means no implementation of the technology. However, the technocracy and populism approach do not take the risk perceptions of the public seriously as they are by definition mistaken. As a result, many risk managers have to deal with this complexity and tend to return to the haven of technical expertise because of its clear-cut solutions

(Renn, 1998). Technocratic and populist pitfalls can also occur in the same debate, for example, by first ignoring the public's opinion and afterward dismissing the technology because of public controversy (Roeser, 2018).

6.1.3 Participatory approach

The third option, the participatory approach, does give the public a constructive role in the decision-making of the technology. Participatory approaches try to involve all stakeholders in decision-making about the risk to comply with different perspectives. A constructive conflict is aimed for rather than settling too early for a consensus that ignores important elements that deserve attention. With this approach, the public has a genuine say in decision-making about a risky technology. Stakeholder values might be incorporated in the technology development by the 'value-sensitive design (VSD)' (Correljé et al., 2015). Emotions could bring light to these values to reach a more thorough moral reflection as well as moral understanding (Roeser, 2018). However, emotions are often seen as obstacles to decision-making because they are considered to be irrational and subjective (Roeser and Pesch, 2016). Consequently, some public concerns towards a specific technology are neglected, which has been problematic in democratic societies.

The interpretations of these values and emotions are the basis of the emotional deliberation approach to risk (Roeser, 2018). The approach rejects the dichotomy between reason and emotion and offers an alternative to the approaches stated above. Here, emotions function as a source of moral reflection and deliberation. This approach could allow us to avoid the common pitfalls and enrich the current participatory approach. By taking emotions into account, morally better decisions and a better understanding between experts and laypeople could be reached. Roeser's (2018) approach might sound more costly, but it would be more effective in the long run. Predictable stalemates can be circumvented by genuinely including the emotional concerns from the beginning.

6.2 ETHICAL THEORIES

As described in Chapter 5, there are many risks involved in genetic engineering. For technologies such as genetic engineering, the ethics should be taken into account while talking about risk management (Asveld and Roeser, 2009). Ethics and risk management foster respect for others to share the same rights to, for example, be safe, independent, and happy. Before starting with an introduction to the theoretical framework, an understanding of normative versus descriptive is required. Normative works try to justify how to act from a moral perspective, whereas descriptive ethics strives for a better understanding of an ethical problem (Dürnberger, 2019). In this research, a lot of descriptive work has been done, and in the end, a more normative view is taken. We can also distinguish concerns that have to do with the nature of the application rather than with the application of genetic engineering per se (Frewer and Shepherd, 1995). In moral reasoning, this distinguishes intrinsic (e.g., naturalness) from extrinsic (e.g., risks) arguments.

Two most fundamental distinctions in ethics can be drawn by the outcome of a decision (consequence ethics), and the means for taking decisions (deontological ethics) (Myhr and Traavik, 2007). These ethical theories are further explained in the two paragraphs below.

6.2.1 Consequentialism/Utilitarianism

The technocracy pitfall follows the principles of consequentialism. Actions are right if it maximizes consequences on an overall, aggregate level (Roeser, 2018). Consequentialism, therefore, relates to CBA where we maximize aggregate benefits and minimize unwanted outcomes. From an act utilitarianism standpoint, the benefits from increased nutrients of GMO products, farmers obtaining better yields, and waste reduction from the process justify genetic engineering development. However, the minimization of unwanted outcomes involves an ethical judgment and cannot be made purely quantitatively. Risk managers, for example, need to determine what kinds of effects to consider in quantitative methods, such as CBA. For these considerations, we need to use ethical concerns such as justice, fairness, and autonomy.

6.2.2 Deontology/Virtue ethics

Non-consequentialist ethical theories such as deontology and virtue ethics object to the principles above because it underestimates the influence of critical ethical considerations (e.g., autonomy, justice, fairness, etc.). For GMO food, it means that we should respect environmental values, other people's well-being, and the autonomous choice of farmers, retailers, and other relevant parties (Siipi and Uusitalo, 2011). These ethical considerations are not involved in the technocratic approach for decision-making on GMOs, which follows the consequentialist path in ethics (EFSA, 2011b; EFSA, 2011a; EFSA, 2013). Hence, we must also consider deontology and virtue ethics for responsible decision-making concerning technology. However, deontology can also be critiqued. It has been argued that potentially fair values can also be biased and that it is often difficult to determine who decides on the norms of behavior (Cross, 1998). The people who mostly choose on these norms have the power of some kind (e.g., religious leaders, governmental officials). However, Roeser (2018) argues that rather than dismissing these moral considerations across the board, we should critically assess and reflect on them by context-sensitive insights and deliberation. In turn, the quantitative approach should inform the ethical assessment. The deliberation process should involve different stakeholders to provide for a broad range of moral insights.

6.3 EXPERTS AND LAYPEOPLE

For risky and disruptive technologies such as genetic engineering, two distinct groups of stakeholders are mostly studied; experts and laypeople. Slovic (2016) and colleagues found that both, laypeople and experts, incorporate other concerns besides annual fatalities into their concept of risk. All people are prone to biases in risk judgments and emotions seem to fit in neither or both systems of Dual Process Technology (DPT) (Tversky and Kahneman, 1974; Kahneman, 2011). DPT, and other rationalist approaches show that there is a conventional dichotomy between reason and emotion. Rationalists argue that system 1 is supposed to be emotional (irrational), whereas system 2 is supposed to be analytical (rational). System 1 (short-term) can be justified by the so-called system 2 emotions (long-term) (Lee and Selart, 2012). However, most ethical decisions deviate from strict rational decision theories. Another important factypeople have a much richer basic conceptualization of risk than experts have. Their concerns possibly reflect to legitimate concerns that are typically omitted from expert risk assessments (Roeser, 2018). There is evidence that risk judgments by laypeople incorporate both quantitative and normative aspects of risks. This means that intuitive judgments can capture more than mere probabilities can tell us. Intuitive judgments might have pragmatic value in allowing us to navigate through a complex world (heuristics), we should not expect them to correctly represent probabilities or relations between probabilities (biases) (Kahneman, 2011). The concerns of laypeople and experts that have been studied by empirical studies point to important ethical concerns (Slovic, 2016).

6.4 MORAL EMOTIONS

As Roeser (2018) points out, many social scientists claim that our moral judgments are formed by spontaneous, intuitive gut reactions (emotions), and our rationality at most works as a posthoc rationalization. These intuitions are defined as feelings or affections because of a particular event (see preface Chapter 1), leading to physiological reactions (e.g., watery eyes) and conscious experience reactions (e.g., smiling). Moral emotions specifically can be seen as doxastic states where the emotions (e.g., sympathy, compassion, shame, and guilt) point to moral values of a situation, action, or person. Moral emotions follow the principles of sentimentalism, where ethics is considered based on emotions (sentiments), not on objective moral truths and rationalism per se (Kant). However, Roeser (2018) argues that emotions and rationality are not mutually exclusive. They are both needed to reflect critically. Roeser (2018) also points out that emotions should critically examine other emotions. Emotions are crucial to understanding moral values, and they involve cognitive aspects. Moral emotions are linked to public welfare or at least of individuals other than the judge or agent (Haidt, 2004). Hence, moral emotions encourage people to do good and to avoid doing bad (Kroll and Egan, 2004). Work from neuroscience support Roesers' (2018) claims that moral emotions are necessary to make moral judgments and up until now, moral emotions have been overlooked (Damasio, 1994).

6.4.1 Ethics and risk

Risk can be defined as a probability of an unwanted effect and can therefore be quantified by the possibility of annual fatalities caused by technology. The policymakers mostly apply a CBA which is considered to be value-neutral, rational, and objective to determine if we should implement the technology or not (Aguilera et al., 2013; EFSA, 2013; EFSA, 2011a; EFSA, 2011b; Bauer-Panskus et al., 2020; Rajan and Letourneau, 2012). However, as said before, studies of experts and laypeople's perceptions show that risk also includes the more ethical aspect, which is different from quantitative risk. Ethical risk refers to unexpected negative consequences of unethical actions that result in negative emotional responses, especially for disruptive and risky technologies, such as genetic engineering, where the effects are unclear. The reaction towards genetic engineering and its risks include lots of emotions, as being illustrated in the preface (Chapter 1). As Roeser (2018) argued, emotional responses are essential to consider for decision-making on risky technologies. The emotions could point out fundamental ethical concerns to consider, which would otherwise be forgotten. The emotional responses have also played a significant role for GMPs and GMAs in the past, which could also be the case for future GMM applications. These strong emotional responses to risk are often created by so-called disruptive technologies that affect the regular operation or industry and displace a well-established product or technology.

6.4.2 Positive and negative emotions

Apart from Roesers' theoretical (2018) work, empirical studies already indicate that emotions can help individuals to make ethical decisions (Widyarini, 2018). For this research, the emotions have been subdivided into positive-negative emotions. The emotional ambivalence allows a person to experience positive and negative emotions all at once, rather than negating the opposite emotion (Briesemeister et al., 2012). When an individual feels a negative emotion, the person tries to do something good to balance the internal state. Research groups already tried to explore the relationship between the acceptance of GMOs, basic emotions, and intelligence (Šorgo et al., 2012; Jurkiewicz et al., 2014). The studied negative emotions (rejection of the technology) are anger, disgust, fear, and disgust. These are conditions in which individuals intuitively react to violations of moral norms. The explored positive emotions (acceptance of the technology) are interest, surprise, and joy. The positive emotions, interest, and surprise are the most frequent responses towards GMOs but are not correlated with acceptance (Šorgo et al., 2012). However, the emotions could point out critical ethical values that should be considered in decision-making processes for a more ethically responsible outcome.

6.5 ANTECEDENTS OF EMOTIONS

As described in the preface (Chapter 1), events corresponding to GMOs activate the emotions of many people. These events or situations are called antecedents, which trigger or elicit emotions. The model in Figure 6.1 depicts common antecedents of emotions related to the risky technology, genetic engineering. From the literature study, it became clear that these antecedents in Figure 6.1 influence the public perception towards genetic engineering. We like to explore how we can study emotions and their link to these antecedents (Roeser, 2018). The emotions can help to determine the antecedents that need to be considered for decision-making on GMMs. Quantitative methods for decision-making (e.g., CBA) tend to overlook these kinds of antecedents, which relate to common ethical issues. We should, therefore, consider emotions to treat all of these issues or do justice to their complexity and inter-relatedness. It needs to be addressed that the antecedents will most likely not be perfectly distinct from each other. Other essential factors linked to GMOs specifically entail 'naturalness,' and the influencing factors 'prior events', 'type of organism', 'type of consumer', and 'type of product'. Recent papers on public acceptance of GMOs (Šorgo et al., 2012; Benjamin C. Heddy, 2017) and the work of a fellow graduated TU Delft student helped to select these concepts (Giezen, 2018).

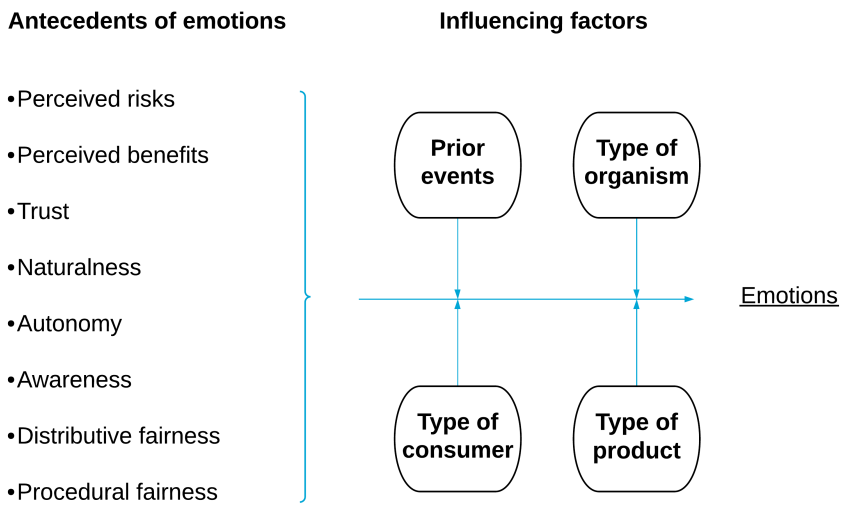


Figure 6.1: This conceptual model represents the relationships between the potential antecedents of emotions and other influencing factors related to GMMs.

6.5.1 Perceived risks and benefits

The benefits and risks of a particular technology can modify the consumer perception and attitudes (Knox, 2000). The introduction of a risky technology with clear benefits can trigger positive and negative emotions, shown in Chapter 1. The absence of any potential benefit of a particular GMO product is enough for rejection. However, when consumers perceive an individual benefit, they are less likely to have safety concerns (Savadori et al., 2004; Miles et al., 2005). However, it remains unclear to which extent perceived benefits 'outweigh' the certain risks (Frewer et al., 2014). Multiple research groups have evaluated the perceived risks towards different GMOs, but a large proportion of people do not know the technology itself neither its possible consequences (Hunt and Frewer, 2001; Scully, 2003). The public perceptions of risks and benefits vary depending on the type of risk, level of understanding, and availability of information about the risk (Frewer et al., 1995).

6.5.2 Trust

Three dimensions of trust exist: rational, cognitive, or affective (Lee and Selart, 2012). The affective dimension is directly influenced by moods and emotions, while moods and emotions indirectly affect the cognitive dimension. Several authors reported that emotional states significantly have an impact on trust and vice versa (Dunn and Schweitzer, 2005; Carnevale and Isen, 1986; Forgas, 1995). The positive emotions such as happiness and gratitude increase trust, whereas the negative emotions such as anger decrease trust. In addition, emotions characterized by personal control (pride and hope) or situational control (sadness) influence trust significantly less than emotions characterized by other-person control (anger and irritation) (Dunn and Schweitzer, 2005). Contrariwise, a lack of trust creates more negative emotions, and confidence makes more positive emotions. Emotions do not seem to influence trust when individuals are familiar with the trustee or aware of their emotions' antecedents. For the individuals to participate and become familiar with the institution or industry, trust-building is needed.

6.5.3 Naturalness

The concept 'natural' is highly valued but genetic engineering is stigmatized as 'unnatural' (Scully, 2003). The technique does not follow the natural order, which is implied as good (Dürnberger, 2019). Different interpretations on 'nature' are taken nowadays, and the emerging concepts are more diverse than the familiar reductionist breakdown of the debate suggests. Consequently, the following questions arise: What is 'nature'?, What are we to understand by concepts of 'nature'? Are these concepts vital to backdrop the controversy? The literature discusses these questions extensively. Statements as 'tampering with nature' or 'playing God' consider the fact that we can make up living things by genetic engineering (Saba et al., 1998). These considerations would link to more negative emotions.

6.5.4 Awareness

The level of understanding of the technology is also essential for product acceptance. A lack of awareness contributes to uncertainties about the technology leading to negative perceptions and controversies. There is a need for people to understand the technology (Ellahi, 1996). The question remains whether the public is more likely to reject or favor genetic engineering as they become more aware of the issues and the technology itself. High levels of trust in a particular industry or company can compensate for the lack of knowledge (Leucht et al., 2010). Trust directly relates to the acceptance level as described Section 6.5.2.

6.5.5 Distributive and procedural fairness

Moral emotions sympathy, indignation, and responsibility point out critical moral values such as fairness and autonomy. Emotional solid responses link to fairness, which can be subdivided into procedural and distributive fairness (Van Den Bos et al., 1997). This distinction is not merely a conceptual one, but it arises naturally in people's cognition about fairness. Procedural fairness relates to the fairness and the transparency of the processes by which people make decisions. The degrees to which people can participate in the decision-making processes around the technology impact procedural fairness and trust. A higher participation rate contributes to a more positive feeling, while exclusion from debates leads to opposing positions (Hanna et al., 2016). Distributive fairness, on the other hand, is fairness in the distribution of rights or resources (Ferguson et al., 2014).

6.5.6 Autonomy

By following the principles of autonomy or freedom, human beings should only be exposed to risks to which they have freely consented (Roeser, 2018). For example, patients treated with specialized nutrition should be free to take this medication in full awareness of the possible risks of the treatment. However, awareness is often lacking while looking at the literature on GMOs. Negative emotions arise when people do not experience autonomy or perceive that autonomy is not being respected or violated. Autonomy is often hard to achieve because technological risks usually consist of collective risks that can affect the public, including people who do not use the technology. Furthermore, the public has to deal with a technology when no alternatives are available (e.g., pharmaceuticals), which can be seen as morally problematic.

6.6 CONCLUSION

In this chapter, we justify using the theoretical framework of Roeser (2018) for this research. The introduction of a risky technology, such as genetic engineering, could bring up lots of discussions (e.g., Chapter 1). Risky technologies, therefore, include more dimensions than only the quantifiable part of the risk. Emotions point to the moral dimension of risk related to specific ethical concerns, which we should not forget to aim for ethically justifiable and democratic decision-making. By focusing on the emotions and their underlying values towards GMMs, we avoid missing out on critical evaluative aspects of risk, and we balance emotions and reason. Scientific methods measure the risks that are important to make corrections to emotions, where emotions provide us with awareness on the ethical parts of risk that are not present in quantitative approaches to risk. For example, an emotion such as disgust might point to the ambiguous moral status of cloning (Roeser and Pesch, 2016). It sometimes explains why people do certain things while the facts tell us something different. Using Roeser's (2018) theoretical framework, our research will support us understand why people will be against certain GMM products while the benefits are clear to the dairy-based industry.

The findings of this chapter helped to improve the structure of the semi-structured interviews, the questionnaire design, and the conceptual model in Figure 6.1. The researcher used this conceptual model throughout this research. It was found that the antecedents of emotions 'perceived risks and benefits', 'trust', 'naturalness', 'autonomy', 'prior awareness', 'distributive fairness' and 'procedural fairness' are all important factors when talking about public acceptance and emotions regarding GMOs. In the following two chapters, we try to answer the first (sub) research question of whether this framework in Figure 6.1 should be different for GMMs as opposed to GMAs and GMPs.

Next to the antecedents of emotions in Figure 6.1, ten (positive and negative) emotions have been selected on relevant literature (Šorgo et al., 2012; Jurkiewicz et al., 2014) and the expert interviews (Chapter 7): anger, disgust, fear, powerlessness, irritation, interest, surprise, joy, hope, and happiness. Van Giezen's (2018) thesis helped avoid missing out on certain common emotions related to risky and disruptive technologies. Lastly, we found that the concepts 'prior events', 'type of organism,' 'type of consumer,' and the 'type of product' play a significant role in public acceptance of GMO products.

7 QUALITATIVE RESULTS

This chapter describes the objectives, method, design and findings of the semi-structured expert interviews.

7.1 OBJECTIVES

The main objectives of the expert interviews were to get more information to feed into and design the questionnaire. We primarily focused on the experts' knowledge and perception of GMMs and their use in the dairy-based industry. Another objective was to answer the first (sub) research question concerning whether there is a difference in ethical concerns between GMMs and GMPs and GMAs. The interview data also helped the experts talk freely about their experience to compare their perceptions with laypeople's opinions at the end of this research. To reach these objectives, meaningful patterns needed to be derived from the interview data using helpful methods described below.

7.2 METHOD

The researcher has used her position to reach out to nine experts working for Danone Nutricia Research (e.g., compliance, legal, marketing departments), the Delft University of Technology (e.g., lab experts, and experts in risks, ethics, and emotions), and other relevant institutions/companies. The experts were related to this topic through their social sciences, policy/legal, or scientific expertise. We performed the interviews to get information on the experts' general knowledge on GMMs, the risks, their and the public's emotions, and ethical concerns. This information helped to supplement the data from the literature study. The interviews have been conducted in English and transcribed by Cisco WebEx software with manual correction. Data analysis was done after transcription by inductive/deductive manual coding (Chapter 7), and personal interviewee data have been stored in a secured database. The quotes in this chapter are in quotation marks and link to the respective experts' professions. The questions were loosely structured to give interviewees more opportunities to express themselves fully. At the beginning of the interview, the questions touched upon more general aspects, such as their work experience with GMMs. Later on, questions were asked that link the technology, moral issues, and emotions. The interview structure with its main topics and example questions can be found in Section A.1. Amongst others the following questions were raised: 'How do you think the public perceives the risks of GMMs?, and how does it differ from GMAs and GMPs?', 'What do you personally think of GMMs in terms of their risks and potential?', 'What emotions related to GMMs are

the most salient?', and 'How should the questionnaire be designed?'. Responses from these interviews consist of five sections; 1) to understand their knowledge on GMMs in general, 2) to understand the expert's knowledge on risks and GMMs, 3) to understand the ethical concerns towards GMMs, 4) to understand the public emotions towards GMMs, and 5) to understand the experts' specific emotions towards GMM technology and its products.

7.2.1 Deductive/inductive thematic analysis

Thematic analysis, and in particular the combined deductive/inductive approach (Figure 7.1), have been used to make sense of the video-recorded semi-structured interview data (Xu and Zammit, 2020). This combined approach allows new ideas and themes to emerge by open and closed coding. For the closed coding, we used preconceived theories and concepts from the literature (Section A.1) (Coombs, 2017). The collected data needed to be transcribed and read to get a first impression to notice relevant concepts. We performed manual coding by selecting and coding interesting paragraphs/words/sentences from the transcripts. These themes and sub-themes belong to a pre-specified category (deductive), or a new category was made (inductive) (see Figure A.1). The categorization was performed by the researcher's knowledge based on the literature study. The interpretations reflect patterns and ideas to compare with literature and construct the questionnaire for phase two of this study. In a later stage of the interviews, we have used an inductive bottom-up approach called 'Interpretative phenomenological analysis (IPA)'. IPA allowed understanding the innermost deliberation of the participant's experience leading to a 'participant oriented approach. The participant had the freedom to express themselves and tell their story how they see it without distortion.

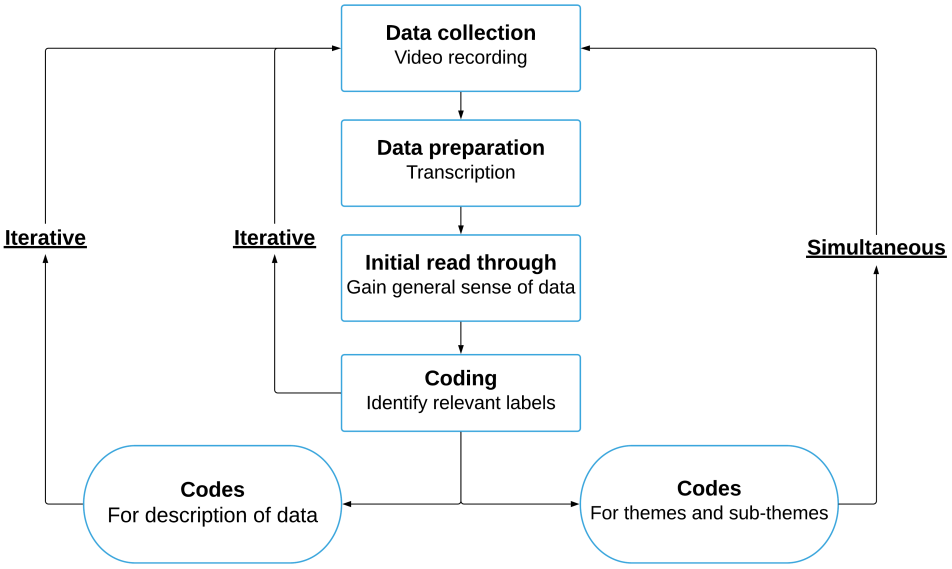


Figure 7.1: A schematic overview of the data analysis of the semi-structured expert interviews starting with the data collection by video recording (adapted from Nowell et al. (2017)).

7.3 RESULTS

The following sections summarize the main findings of the expert interviews. The first sections (Section 7.4 and Section 7.5) discuss the interview results on examples, advantages, and disadvantages of GMMs in the dairy-based industry. The next sections (Section 7.6, Section 7.7, and Section 7.8) focus on GMMs related to its risk, regulations and ethical concerns. The last sections addresses the topics trust and emotions towards GMMs (Section 7.9 and Section 7.10). At the end of this section, the conclusions present the main take-aways for discussion and questionnaire design (Section 7.11).

7.3.1 Experts

The interviewees are scientific experts in biotechnology within technical, social sciences, public affairs, or policy-maker positions. The quotes in the following sections are anonymous, but they link to the expert numbers in Table 7.1.

Table 7.1: Information on the types of experts that were interviewed and relate to the field of biotechnology.

Expert Type	Number	Information
Technical	1	Enzyme strategist
	2	Director R & I
	3	Bioprocess director
Social sciences	1	Assistant professor Biotechnology & Society
	2	Professor Biotechnology & Society
	3	Advisor at scientific advisory body on GMO
	4	Advisor at scientific advisory body on GMO
Public affairs		Emerging Food-Related Risks Director
Policy		Policy manager

7.4 EXAMPLES IN THE DAIRY-BASED INDUSTRY

At the beginning of the interview, all technical experts were asked to give examples of successful GMM products in the dairy-based industry. Examples of processing aids (enzymes) were given, such as the rennet extractor for the cheese industry, which already showed many variabilities and solved many issues. But also food ingredients such as human milk oligosaccharides (HMOs) are currently only produced by GMMs based on bacteria. Nowadays, the dairy-based industry mainly focuses on creating processing aids, which are GMO-free, from a regulatory point of view (Figure 5.2). However, according to technical expert 2 the future potential of GMM technology is clear, "Take for example HMOs for which the structure-function can be brought closer to human milk. This enhanced version of HMOs most likely contains complex proteins or other traces of the micro-organism." On the contrary, dairy-based companies can also use GMM technology for direct enzyme therapy, where people take in enzymes to help their digestion. Or think of particular GMM material that requires immediate consumption to treat patients with metabolic disorders. Technical expert 1 feels that the discussions with spe-

cific stakeholders about enzyme engineering increase. There are many opportunities to make enzymes work at high temperatures and different pH (a scale used to specify the acidity or basicity of an aqueous solution). These enzymes refer to artificial enzymes because they do not exist in that form in nature. Danone's and many other dairy-based companies' current position towards these products is negative, but it is something to evaluate for the future.

7.5 ADVANTAGES AND DISADVANTAGES

From all expert interviews, it is clear that the advantages of GMMs far outweigh the disadvantages. Technical expert 1 points out, "Processes can be made much cheaper and products much purer." It could also be a way to access new functionality in the products and leverage the potential novel products. It is becoming clear that ingredients, not just enzymes, amino acids, and vitamins, are interesting to produce on a large scale. However, the technical experts also see that the dairy-based industry would need a different business model to address the essence of the application. The social sciences experts believe that the main issue relates to the media and resistance groups and how they would affect the dairy-based industry. According to the technical experts, we need to leverage this tool as there is no genetic material in the end product. Then the main problem is left with the policymakers who anticipate that the public may be skeptical. Other issues relate to the existing value chain of a specific product. Think of emotional responses that relate to a societal and political transition. Technical expert 2 mentioned that "You cannot stop progress in science, and I am aware of significant technological changes. Think of the first machines when people with horse carriages lost their job. There are always transitions happening which also lead to an opportunity to create more jobs."

7.6 RISKS

The technical experts believe that the risks of GMM products that are made in contained environments are very low. The enzymes, for example, are relatively short-lived, and the DNA cannot go outside of its contained environment. Apart from the perceived environmental risk, they believe that consuming GMOs' threat to human health is shallow. Technical expert 3 mentioned, "There is no health risk to eating them because you know that we eat DNA all the time. It is not going into your cells or anything." However, if you start introducing new ingredients such as alternative proteins into the mainstream diet, there is a risk of allergies, which needs assessment. The policy expert emphasizes that there is still a lack of clarity on the risk assessment guidance documents of the European authority. Especially for companies and start-ups who do not have dedicated people working on regulatory affairs, could benefit from expert advice from consulting firms specializing in shepherding these kinds of applications. The more novel the technology, the less money there is for the proper assessment. Companies have quite an opportunity to be propositional in terms of safety aspects to be assessed. Furthermore,

they also experienced that people who make the current risk assessments are not experts in the respective technology. Until now, GMM products do not seem to be in the mind and consciousness of most policymakers who work on food; it is relatively under the radar.

We identified that the GMM product risk is an essential factor for product acceptance from the literature study. There is a struggle for policymakers where they feel they have to be very careful with safety. They might value security more than possible benefits. Currently, technical experts agree that the regulation is so strict that there are many things you cannot do as an innovator. The policy expert also thinks that it is too restrictive, but they also see that it is good to have different opinions and be careful. The problem with safety is that people can understand it in various ways. All technical experts see the benefits of having a more flexible risk assessment method to take a bit more risk to gain more knowledge. The technical experts also think that they and the public would accept the technology when the benefits outweigh the risks. For example, if this technology can bring something to society by adding value to a product or creating a valuable product that does not exist in nature. Technical expert 2 sees all the positives from moving away from current production systems harmful to us, the environment, and animals. "I would be happy to make that calculation", technical expert 2 said. However, the social sciences experts wonder if the public is also ready and if we should be transparent about the risks. Most social sciences experts think that the public is likely incapable of distinguishing between the different GMM products and will not play a significant role in product acceptance. They believe it is more about the overall inherent positivity linked to labs and safety. With this having said, the intrinsic values based on emotions and ethical concerns would be the basis of the problem rather than the consequences (Frewer et al., 1995). The social sciences expert 1 stressed that, "It has to do with risk perception and that we have the idea that it must be 100% safe while in everyday life, we accept lots of risks."

7.7 REGULATIONS

At the moment, different sets of regulations hold for GMM use in a contained environment or deliberate release. And, in Europe, no GMO is allowed in the final product. The technical and policy experts do not see a problem in legislation for implementing products from enzymes in a contained environment. The EFSA accepts these products if well purified, and there are no problems with other regulatory bodies. On the contrary, GMM products can be released in wet mass for fermentation and end up in yogurts. If such a product is thrown in the bin, the material can multiply. So, in terms of regulation, the public affairs expert 5 addressed that contained environment and deliberate release are two different avenues. However, the technical experts believe that implementing GMM products from a controlled environment would be more a media issue than regulation. They mentioned that "The public has been psyched up over the years about Frankenstein food and all of this." A different problem regarding regulations is the organic products, which are now regulated privately, and for the moment, they do not get approval. Nowa-

days, enzyme suppliers offer dairy companies several GMMs detection analysis methods to ensure that products comply with the zero-tolerance rule.

However, the technical and policy experts agree that the European Union (EU) must alter the GMMs regulations to a case-to-case basis. A zero-tolerance policy is not reasonable. The potential of GMM products is high in terms of sustainability and medical reasons, and some products cannot be completely GMO-free. This change would not mean lesser regulation but more specified on a case-by-case scenario. Once DNA is detected, the product must contain the GMO label and exclude various processes that potentially support sustainability goals. Since more products involve GMMs, a vast bank of analytical probes must comply with these strict rules. How this zero-tolerance policy is affecting dairy-based companies remains to be unclear. The public affairs expert notices that people knock at their door too late. Up until now, they are not informed about possible issues with GMM regulation.

7.8 ETHICAL CONCERNS

"I think there could be a lot of ethical concerns about the whole area of GMM because we have opened a sort of Pandora's box here, where the opportunities are enormous." - Technical expert 1

All experts agreed on the importance of ethical concerns while developing and studying the potential of GMMs. Even if the product is not in an application of approval, policymakers are very skeptical about consumers' perceptions. And, just like the risk assessment, technical experts stress the importance of case-by-case studies. As technical expert 2 said, "It is not an ethical question about GMMs or GMOs. It is an ethical question, case-by-case. What is the GMM going to do? What is the GMM? What is the objective of doing this manipulation? And that is where ethical questions arise." From this result, it was possible to conclude the first (sub) research question. It implies that a specific organism would link to specific ethical concerns, but more factors would matter. We, therefore, argue that distinctions can be made by ethical concerns towards, for example, type of organism, type of product, and type of consumer. They could all have an interrelated effect on public perception. However, the social sciences experts also think that the public would be more against any modification, which has more to do with the trust and naturalness of the technique, which we will discuss in the next section.

7.8.1 Type of organism

From the interviews, it became clear that all experts frequently subsume GMMs under the overall GMO topic. Discussions remain in the GMO context because that is the preconceived attitudes that are clear. However, the policy expert sees the relevance of having conversations to a level where those nuances are appreciated. The policy expert mentioned, "Environmental non-governmental organizations (NGOs) that have an anti-GMO stance on, for example, crop cultivation, might in practice not object against GMMs in a contained environment." However, there

are also groups that are very strongly anti-GMO, irrespective of the environmental exposure. The public has limited experience and would therefore speak out against GMOs regardless of the specifics. It remains to be unclear how the public perceives specific products from GMMs. The experts hypothesize that public reaction towards products from GMAs is more sensitive. However, the social sciences expert 3 said, "Many people are concerned about animals and welfare, but on the other hand, they do buy cheap pieces of meat. There seems to be an imbalance there." The social sciences experts believe that the sensitivity factor would not differ for micro-organisms and plants. However, they expect people to fear GMPs more than GMMs because we can see plants more than micro-organisms.

7.8.2 Type of product

The technical experts hypothesize that the product type (contained use vs. deliberate release, organic vs. inorganic, medical vs. non-medical) impacts how the public perceives the risk. When using clear product targets in an ethical sense to bring better nutritional value, higher efficiency, and better quality value to the product, the technical experts do not see any ethical issues. Technical expert 2 said, "I am very open to GMMs if it is for a certain purpose. Such as stating that this basic bacterium also has a protein, which is usually not even produced, but this is very good for you." Then the only important factor is its safety and the category you are playing in. Apart from product safety and its effectiveness, social sciences experts agree that emotions play a significant role. Especially if we speak about medical, then all experts think people do not care. If you are talking about general food, then they believe that consumer acceptance is low. So, what about medical food and food which brings an added nutritional value? The targets for medical food are less clear than pharmaceuticals because it does not direct to one problem (e.g., insulin to treat diabetic patients). The sufficient details of a medical food product can be at stake and need clear communication. However, most experts hypothesize that the public is ready to have value-added ingredients in their food to keep them in good health and have reasonable prices. Furthermore, they believe that the products need to positively trigger society by, for example, giving work to many people. As technical expert 2 said, "I would be happy as the deserts of this world would produce algae with the sunshine over there and then have many bioprocesses ongoing."

When discussing the specific genetic modifications that deliver the GMM product, technical expert 3 thinks that the acceleration of some potential micro-organisms within its genetic material is acceptable, even if it is leveraging as a GMO. However, when starting to play with different genus, they think we need to be cautious when communicating about the products. "Chimeric ingredients can frighten the consumer", technical expert 3 said. Talking about foreign living DNA cultures in our product is something that the technical experts, even consumers, are not ready to find. They believe the acceptance is there if we speak about precise DNA modification in micro-organisms by promoting or speeding up some natural genes and extracting the protein from them. Another issue relates to organic products, where naturalness plays a significant role, and therefore, it is not always possible to use

GMMs. Dairy-based companies need to sell organic products with an organic label, which means that even GMM in contained use is forbidden. "That is the rule now; if you do organic, you do not use genetic engineering," public affairs expert said. The vitamins B12 or B2, for example, must be produced by GMM to supplement babies. The consumers who strike for organic products cannot enrich their products with these vitamins.

As introduced in Chapter 5, we distinguish three types of product for this research; copying general food, medical or value-added food, and foods where the alternative is unethical. The experts gave examples for each of them. A GMM product can copy a natural product by making the product environmentally friendlier. Instead of cutting the jungle to get palm oil, a fermentor with algae can now obtain the oil. You would not consume as much land, and you are still in power with the ingredients. The second option is optimizing micro-organisms and their products that are not there naturally. You would let a *bilfidus* produce compounds or antibodies which are usually not there, which are beneficial for you. We can think about harvesting human breast milk to supply infant milk for the final product category, which would be unethical (see Section 5.8.1 for explanation). The mindset can essentially be changed if there is no other option to produce a particular product or the product has a life-saving potential. Most experts think that accepting these products is much higher, which must be investigated further on medical food.

7.8.3 Type of consumer

The experts hypothesize that the behavior towards certain GMM products would also depend on the targeted type of consumer. The experts from Danone Nutricia Research felt a clear distinction between the legal and quality departments when discussing genetic engineering. Those two departments, legal and quality, look at the current context and have difficulties projecting in the future. Quality and safety departments rely on facts and data. Most experts do understand that people are reluctant to biotechnology as a whole. And apart from the public, the social sciences experts do see the consumer organizations or NGOs that strike for a green and sustainable environment (e.g., Greenpeace) to be the ones who could start the fire. Most experts also think that the awareness of the consumer would play a significant role in the acceptance of GMM products. A certain level of information would matter, according to social sciences expert 2 (Section 7.9.4). When social sciences expert 4 asked students about GMO food labeling, they thought GMOs are in every product, referring to modified starch. These products are chemically altered and not genetically modified. So, if the people are not well educated, do a shortcut and vision that gene editing is demonized. Then most experts think that it might become problematic in the future for biotechnology, but this remains unclear for GMMs in contained environments.

All experts hypothesize that a patient will be more willing to buy the GMM product because of certain advantages. Think, for example, about porcine insulin and recombinant insulin. The technical expert 2 believes that when someone is a diabetic person depending on insulin, they will go for the recombinant one, identical to those humans produce. The social sciences experts also stress the influence of demographic variables and emotion towards their choice of food products. "It is not for nothing that the alien pieces of fruit go elsewhere," social sciences expert 3 said. It seems to be important how it looks and that we are free to choose. But, the experts believe that if you have a specific condition or an allergy and you are a patient, you look at the technology differently because you are happy if there is an alternative product. While looking at the Netherlands, the food pattern has primarily changed over the past 30 years. In the interviews, it was a recurring topic that consumers like the very old-fashioned or organic way to produce food products. We have this so-called nostalgic idea of how food companies should make our food—for example, farmers with their hands in the ground instead of the big machines. Or think about religious reasons, so that Muslims prefer the recombinant insulin over the porcine insulin. Another critical point is the generation difference. Most experts hypothesize that younger people look at GMMs differently and that trust in specific information sources plays a significant role in this. The more youthful generation already has much technology that has an intensive impact on their lives.

7.9 TRUST

Apart from the above considerations, experts also believe that the public would be against any product from GMMs. The acceptance would have more to do with trust and the intrinsic value of the technique.

7.9.1 Prior events

We found a recurring pattern in the interview data for the ethical concerns about prior awareness due to historical events. An example is when companies tried to extend their roundup by more pesticides, which destroyed every other plant in the environment. Companies would like to bring pesticide-resistant crops on the market. They combine the breeding of the seeds and its treatment altogether under one control, which is only profit-driven and not so much saving the world hunger. Or think about the Ecover case, which developed biological detergents from modified bacteria instead of palm oil. A dogmatic situation results in pro gene technology and people who are absolutely against gene technology. Technical expert 3 hypothesizes that we would always have these extreme cases because of the missed opportunity and few transparencies due to this dogmatic situation. When GMOs got out into the media, the whole area of GMOs got tainted with these events straightaway. "It is not easy to come back on by saying that we can also do good things with genetic engineering," technical expert 1 said.

The public affairs expert worked for 23 years on GMOs concerning regulations and social perception. There has been almost no fuss or negativity from NGOs and media on GMM products from the contained environment in the past years. "The GMMs were not many, and the products were not touching mother nature; the GMMs have almost been no topic," public affairs expert mentioned. However, the companies (e.g., Monsanto) that used the deliberate release form of GMOs did a lousy job in communication by lying and showing no transparency. Because of these events, supermarkets took away the products while only 20% of the consumers avoided buying GMO food. The social sciences expert 2 believes that the product removal happened because of the supermarkets' fear of organizations that might create fuss and harm the brand name.

7.9.2 Company image

Like many other dairy-based companies, Danone is GMO-free and must follow the regulations and confirm that no GMO material is in the final product. Danone Nutricia Research experts are afraid that if one of the non-ethical applications is reaching the public's attention and pressure groups, the whole area would be tainted with it. The mission of Danone is 'One Planet, One Health,' and like other dairy-based companies, they would like to maintain this vision. The technical experts feel pretty uncomfortable managing and handling the spread of a microorganism, which frightens them in a virus context. Nowadays, dairy-based companies are striving to reach specific sustainability goals in the future. Most companies invest in GMM technology because of this reason and when it is more economically beneficial. At the same time, the social sciences experts believe that consumers should have the freedom to choose between the more innovative or, the more traditional products. For dairy-based companies to have flexible postures, it is essential to accept that there is a wide range of consumers. The experts not working within Danone Nutricia Research are of the opinion that the brand name 'Danone' is trustworthy when referring to infant food. Apart from Danone, they also trust the food market for testing it or putting something on the market and safe. On the other hand, they think that pharmaceutical companies have a very bad reputation. "It is therefore important that Danone does not situate itself in that kind of field," social sciences expert 2 said. Pressure groups and environmental NGOs who are for some reason against GMMs could harm this company's image, especially when companies show non-transparency. In this way, the media will no longer be the primary concern because they will only write about the products once they are on the competitive market. The social sciences experts stress that the problem is the environmental NGOs and politicians with strong opinions.

7.9.3 Framing

From expert experience, there is a consumer disconnect when a product is communicated in a technology-oriented way. The technical expert 3 said, "If you start to speak about fermentation about the process. You see a disconnect in the consumer world." Experts think that the products from GMMs are not a category in the public's mind when it comes to food. It is more about the name of the pro-

cess or product, for example, fermentation, beer, or yogurt. Technical expert 3 mentioned that the communication should go about fermentation produced instead of recombinant ingredients. From their experience, even if the consumer does not understand fermentation very well, the term is more attractive and has a more positive halo. The public perceives fermentation as a process that is quite traditional, slow, and natural. The technical experts also think it is essential to address the disconnect between the micro-organisms used as a cell factory and the final ingredient in a simple way. They believe that there is a way to tell the process, and there is maybe not one that fits well, but it needs to be adopted by the situation. Another thing that all experts addressed is to focus on the communication of the social benefits, product benefits, and sustainability benefits. As a dairy-based company, you would have to be transparent on the risks, but you would also say this is an opportunity you would not even find in nature. Or the technology could help to bring down the burden on the environment. "If the framing is more substantiated towards these benefits, this might help people accept the products," social sciences expert 2 said. From experts' experience, we can also learn that when companies try to reassure that a product is safe, people tend to become extra suspicious. Social sciences expert 3 gave the following example of a statement that is often made, "I will explain it one more time, and then I will tell you factually how it is." Instead, the social sciences experts believe companies would have to show and explain that they follow strict regulations and take them into account, but there are still some minimal risks. Companies would need to stress that they do everything to avoid it, but they think it is worth taking the small risks because of the benefits.

The social sciences expert 2 found that lots of literature on GMOs focuses on information provision. People perceive the information in a specific way that is influenced by certain underlying values. What the social sciences experts think is very important is the trust factor, to address benefits, and to be open to criticism.

7.9.4 Information flows

A couple of information sources could trigger a public controversy towards GMMs in the dairy-based industry. Currently, we are living in a pandemic situation which has led to more information flows about vaccines corresponding to GMM research (Belderok, 2021). The social sciences experts stress that the pandemic could stimulate more discussion around healthcare and medical products derived from GMM. They emphasize that there is a certain level of information that leads to trust. If that is not an issue, the data can be simplified and communicated to different key opinion leaders and consumers. According to technical expert 3, key opinion leaders and consumers are the two territories where we know that communication flows. However, at the same time, the social sciences experts are not sure about the level of information to communicate on GMMs. They hypothesize that it would be easy to influence the public by the Internet, newspapers, blogs, or Instagram. Social media spreads information quickly and leads to a lot of mixed material, which would explain the vast diversity of opinions leading to public controversy. However, the technical, public affairs, and policy experts emphasize the

need for education to understand the products to increase product acceptance. Today Danone Nutricia Research closely works with universities and publishes a lot with external partners. In this way, Danone Nutricia Research tries to acknowledge public discussion. Activists and environmental organizations can access these documents and check the used methods. Participation and science have been stressed in multiple interviews, but the stakeholders' involvement has often been seen as a checkbox without consensus.

However, social sciences expert 2 stresses that there is no need to educate the public more. "You cannot change the negative vision towards genetic engineering by rationally providing information. People are not interested in the information and do not pick it up. They believe that something is behind it." Accepting GMM products would be more about who is giving the information, whether it is the government, the company, or universities.

7.10 EMOTIONS

Interestingly apart from the social sciences experts, the scientists and policy experts do not discuss the emotions and try to avoid the topic. They mention the emotional aspects of the technology as irrational but do see them as the driving force but just harder to address. However, they believe that product acceptance is coming from deeper emotions when thinking about the framing. The policy expert, for example, talked about the marketing of meat in a petri dish, which did not reveal the positive emotions from laypeople but anger and fear instead. Also, the technical experts have been studied to be afraid of the consequences. Technical expert 1 mentioned, "If you just open the door to this, we are all going to have all sorts of bad things coming out of it." Most experts believe that the negative emotions towards GMMs would mainly link to the awareness, trust, and prior events. And that the positive emotions towards GMMs would especially relate to the benefits and faith (in product, company, and industry). According to social sciences experts, it is a strong reaction when someone's reaction is fear to technology. They believe, therefore, that it is essential to determine the emotions and their antecedents and use them to decide on risky technologies. In this way, we can use our deep feelings to better society by developing something that helps the community. The social sciences expert 2 stressed, "The benefits can be environmental, economical, but you will hit much more emotions if the benefits are social."

Example from social sciences expert 2
"50% of our climate action program relates to biomass and a lot of other biomass-related production ideas, which are very beneficial to lots of parties. However, problems arise in the decision-making whether to implement the related technologies or not. But, what is the alternative? You have wind, or you have solar panels, but with those, we do not get social development because their production units are in China in Norway in Sweden, Germany, etc. The production is in the rich western world. At the same time, the majority of the problem will be felt and is already in the sub-Saharan and Latin American, and Southeast Asia countries. Here,

the population growth is much higher. Hence, the difference between developing and western countries is the problem that we should tackle rather than whether we should use biomass or not. Energy is the motor for social development. So, my argumentation is that biomass is their only way to make clean water, energy and make social development happen as long as we help them. So then I put it to the emotion, the less developed area, and the emotion of children without foods. With biomass utilization, you can improve your agricultural system, which is necessary there. And, that will be the motor for sustainably feeding the world. So I would take the emotion of the less developed areas and treatment of patients as a starting point for justifying the use of biomass."

So, the social sciences experts believe that dairy-based companies could reach the product acceptance of GMMs by targeting the groups that can awake an emotional feeling. Groups that need the technology the most or benefits the most from it. Another way of using emotions is to link GMMs to trends that people would like to belong to.

7.11 REFLECTION OF INTERVIEWS

The findings from the expert interviews say that the EU regulations are very restrictive and ultimately ineffective. These regulations were needed to increase trust after the lousy implementation of GMO products. The experts believe that these prior events provide significant loopholes for using GMM products. The regulatory definition of a GMO seriously hampers innovation even for low-risk modifications with high potential to help society. As a result, Danone and many other dairy-based companies' current position towards end products containing GMOs is negative. We focus on non-GMO-containing end products by GMMs in a controlled environment for the next phase of this study.

This chapter helped answer the first (sub) research question on whether it would be relevant to consider the ethical concerns of GMMs versus other GMOs differently. From the interview data, it seems that it is a moral question case-by-case, which implies that it is essential to look at specific products, targeted consumers, and their feelings that belong to them. According to the expert's opinions, the exact type of organism would matter, but it is more than that. They believe that trust and faith in the company and its industry are crucial factors for accepting GMM products. For this research, we wanted to study the emotions and these ethical considerations on a case-by-case basis. In the next phase of the study, we, therefore, focus on the dairy-based industry and the three product distinctions described in Section 7.8.2, which relate to medical food products. Experts agree with the relevance of this research since it is new territory, not only medical and not solely food. They prefer anticipation and avoiding future crisis management because they see the possibility that some crisis could happen that could touch biotechnology as a whole. The experts advise creating different scenarios of what the future might look like and what role the specific GMM product might play. These scenarios could help to broaden laypeople's reflection particular to these cases.

The interview data clearly show that the emotions have been forgotten and are seen as irrational. The moral emotions which are related to health could provide essential insights into the ethical considerations. For example, the feelings of responsibility and fairness could lead to more interest in the technology when applied to patients. The feelings would help to understand the moral impact and motivation better than from pure scientific info. It is essential that people believe and see that this is an opportunity for humanity and society, not just making rich companies richer.

7.11.1 Questionnaire design input

From the expert interviews, we can conclude that the antecedents of emotions with regards to GMOs also hold for GMMs (see Figure 6.1). As obtained from this chapter, experts believe that the emotions and ethical concerns differ on case-by-case basis. We chose the antecedents of emotions in Figure 6.1 to study laypeople's perceptions by using an online questionnaire, described in the following chapter. With the help of the online questionnaire, we explored the relationships of these antecedents with the ten emotions mentioned in Chapter 6. In Chapter 6 we argue that the emotions and antecedents could help to point out essential ethical considerations for decision-making. In addition, we obtained the following statements from the interview data. All experts do not necessarily endorse these propositions, but they give a general understanding as input for phase two of this study. The next chapter has put a more specialized product focus on scenario-building since we considered this essential (regarding the answer to SQ1).

The following propositions relate to the perception towards genetic engineering:

1. A dichotomy is present: pro and con genetic engineering.
2. The trust level of food companies is high.
3. Social media is the main information flow.
4. The perceived benefits outweigh the perceived risks.
5. The perceived risks to human health and the environment are deficient.
6. Risk and benefit perceptions differ per generation.
7. Low awareness results in a higher level of concern.
8. The type of consumer affects the more positive attitude towards genetic engineering.

These propositions relate to the perception towards GMMs in a contained environment:

9. The acceptance would be more significant for GMMs than for GMAs.
10. The public is ready to learn more.
11. The type of product (e.g., general food product or medical food product) affects the positive and negative emotions.
12. The emotions are linked to benefits, prior awareness, and trust.

The following chapter, Chapter 8, shows descriptive results that support these propositions that came out of this first exploratory part. The experts made lesser propositions about the emotions and their possible link to ethical concerns. The questionnaire would help to explore this link with the help of product-specific scenarios.

8 QUANTITATIVE RESULTS

This chapter describes the objectives, method, design and findings of the online questionnaire.

8.1 OBJECTIVES

The main objectives of the online questionnaire were to gain new insights into what the public perception is towards GMMs and to compare this with the results from the expert's propositions (Section 7.11.1). Another objective was to explore the relationships between the ten emotions described in Chapter 6 and the antecedents of emotions that could point to ethical concerns (Figure 6.1). In this way, we tried to study the gut feeling's response and empirically use the theoretical framework of Roeser (2018). A questionnaire needed to be designed to reach these objectives, and the results required to be analyzed.

8.2 METHOD TO STUDY EMOTIONS

There are multiple ways to study emotions and usually a more interactive and physical method is used (e.g. focus groups). However, these methods were not chosen because of the timing (summer period) and the pandemic. We have asked the respondents from the semi-structured interviews (Table 7.1) how to study emotions in a questionnaire format. Based upon the literature search and expert interviews, genetic engineering is a sensitive topic with multiple related events that create a negative gut feeling approach. Hence, no information sheet has been provided before the questionnaire. We did this to study the respondents' current and status quo knowledge without manipulating them. We also tried to avoid using too many technocratic words since experts' found this could influence the respondents' reaction and hamper participation. Furthermore, from the answer to the first (sub) research question it is known that it is essential to study the perception towards specific products on a case-by-case basis. We, therefore, chose to design specific scenarios to study the reactions that could be linked to them. The social sciences experts (Table 7.1) advised creating different scenarios of what the future might look like and what role the specific GMM product might play. These scenarios could help to broaden people's reflections particular to these cases.

8.2.1 Scenario-building

We constructed scenarios based on different literature studies (Boenink et al., 2010; Šorgo et al., 2012). There are existing tools to anticipate soft impacts related to human relations, values, and identities. However, these methods do not acknowledge the mutual interaction between technology and morality. Boenink (2010) proposes a three-step framework to build techno-ethical scenarios in such a way to have a dynamic view on moral principles and time frame. Boeninks' (2010) approach has been used to create future scenarios of the genetic engineering technique and its application on micro-organisms in the dairy-based industry. We created two types of surveys for this research, where we made a distinction in scenario descriptions. One survey with all information included would be too lengthy and time-consuming. In both questionnaires, a special dairy-based GMM product was compared with a general dairy-based GMM product, an animal-free yogurt. The special products represent a product where the natural alternative is unethical (version 1) or a medical food product (version 2). See Section A.2 for the product scenario descriptions.

The author wrote the first draft of the scenarios with the help of the literature and additional information from the interviews. The focus has been put on the hypothetical emotions and antecedents of emotions that could point to ethical concerns (Figure 6.1). The scenarios were repeatedly discussed with respective supervisors from Danone Nutricia Research and the Delft University of Technology. The outcome of Chapter 7 and the goals of Danone Nutricia Research helped to narrow down the extensive scenarios to product-specific scenarios to study:

- **Type of process**
  To study the public perception towards genetic engineering in a contained environment. Hence, the products categorized by deliberate release were out of scope.

- **Type of product**
  To study the public perception towards a product where the alternative is unethical (e.g., human milk oligosaccharides), a product to treat patients with a metabolic disorder or allergy, and a product for the general consumer. Hence, other interesting products such as gene therapy were out of scope.

- **Type of consumer**
  To study the influence of demographic variables that relate to being familiar with genetic engineering and generation. Only Danone employees and students (18+) from the Delft University of Technology have been asked to participate. Hence, children and significantly older people were out of scope.

- **Prior events**
  Previous events, such as strikes related to genetic engineering, have not been extensively described in the questionnaire to avoid manipulating thoughts.

8.2.2 Target groups

Since this research touches upon confidential material to Danone Nutricia Research, our target groups were limited to students from the Delft University of Technology and employees of Danone. People from both institutions were asked to aim for a more age-distributed sample and look for possible differences between departments, which was part of the expert's propositions. The questionnaires were distributed with the help of the researcher's position and network within Danone and the Delft University of Technology. Both questionnaire versions were distributed in these two locations. 84 students from the Delft University of Technology and 90 employees of Danone Nutricia Research completed the online questionnaire. All respondents were based in the Netherlands but could have a different country of origin. We have asked students and employees from various faculties and departments, excluding Applied Sciences and Enzyme-related research, to target people without an academic background in biotechnology or genetic engineering. In this way, we try to target people who have more or less the same knowledge as general consumers instead of experts on this topic.

8.2.3 Types of questions

The questionnaire consisted of a quantitative and qualitative part. The qualitative part (open questions) is known to be more time-consuming in terms of coding to analyze the text, just like numerical data (Gideon, 2012). The quantitative part (closed questions) of the survey asks questions about general preferences or items which are easy and quick to answer. The closed questions were responded to by multiple-choice or by a 6-point Likert-scale. Depending on the question, the scales ranged from 'weak to strong,' 'strongly disagree to agree strongly,' 'very unconcerned to very concerned,' and 'very mild to severe.' In total, there are six options, including 'neutral,' 'I do not feel this emotion, or 'I do not know (or does not apply).' For the multiple-choice questions, more answers than one were possible, and this was clarified in the respective question.

8.3 SURVEY OUTLINE

All the topics that have been touched upon can be found in Section A.2, with the questions and answer possibilities in specific order (Figure 8.1). Before the study, the respondents were given a small introduction (section 1), including information on the study purpose and relevance. The respondents were asked to agree with the informed consent to use further socio-demographic data such as gender, country of origin, age, and education. When the respondent was a Danone Nutricia Research employee, they must indicate the respective department where they work. When the respondent was a student of the Delft University, they must tell the individual faculty where they study. The second section of the questionnaire related to understanding genetic engineering in the dairy-based industry (section 2). The respondents have been asked to answer questions according to the technique, how it works, the scope, and understanding of the technique. The following two sections (section 3 and section 4) consisted of the product-specific scenarios.

The respondents were asked to imagine themselves as a consumer (patient versus non-patient). They were asked to describe their emotions and feelings after having read the techno-ethical scenarios. These scenarios have been used to describe three different purposes of a product produced by a GMM in a contained process. These three products have been selected based on literature and the interviews, as described in Section 5.8.1 and Section 7.8.2. The respondents were not given any extra information about what this would mean for them regarding costs, risks, and benefits to express their initial thoughts and feelings. Respondents were asked how strongly they experienced the ten emotions described in Chapter 6. They were also given the option 'Does not apply' or 'I do not know.' In the last section (section 5), we asked questions to study the risk the public perceives and their future interest. The general overview of the survey is given in Figure 8.1.

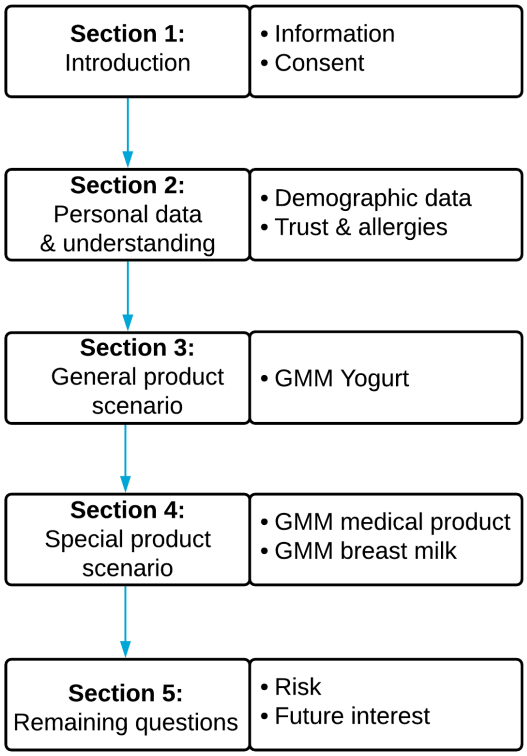


Figure 8.1: The outline of the survey from start to end with corresponding relevant information. The details of version 1 and version 2 details can be found in Section A.2.

8.4 DATA COLLECTION AND DATA ANALYSIS

With the help of Microsoft Forms, the data were collected between July and August of 2021. Invitations to the online survey were distributed through Whatsapp groups of students from the Delft University of Technology or the WorkPlace chat groups to reach out to Danone employees. The samples were created by using the researcher's network. The Danone respondents were randomly selected from a list provided by the Human Resources department. The link to the survey was provided after interest was shown by a personal message because of confidentiality. Hence, no links with direct access to the questionnaire were distributed. The questionnaire was fully self-administered with six open questions and 29 closed questions. The respondents completed the questionnaire in approximately 19 minutes.

For open questions, word maps were generated and coded by pre-specified codes. SPSS software was used to test for significant differences. The data have first been converted to numerical numbers to use SPSS for further analysis. The Kruskal–Wallis H test was performed to study differences between three or more independent groups on an ordinal data set. The Mann-Whitney U test was performed to study differences between two independent groups on an ordinal data set. Prior to these statistical tests, Levene's test was used to determine the homogeneity of variances. All statistical analysis was carried out using SPSS software with a confidence interval of 95%, and conclusions were drawn using a p-value of .05.

8.5 SAMPLE VALIDITY

In total, 174 respondents completed the surveys (Table 8.1). 85 respondents completed the surveys with the scenario description of the special product 'version 1,' and 89 respondents completed the surveys with 'version 2' (see Section A.2). The inputs from several respondents were removed since they reported to be studying at the faculty of Applied Sciences or Industrial Engineering that were not in the area of interest for this study. In the end, 171 out of the original 174 respondents remained.

Table 8.1: The distribution of respondents by institution and product scenario version. *The details of the scenarios can be found in Section A.2.

N respondents	TU Delft students	Danone employees	Total
Version 1*	39	45	84
Version 2*	42	45	87
Total	81	90	171

8.6 SOCIO-DEMOGRAPHIC VARIABLES

The questionnaire was distributed among people that are based in the Netherlands. The country of origin could differ, and other socio-demographic variables that were obtained from the respondents were gender, age, faculty/department, medical food requirements, allergies, and educational level. The gender distribution of both surveys is given in Table 8.2.

Table 8.2: The distribution of respondents by version and gender. (Q1 - Section A.2)

N respondents	Version 1	Version 2	Total
Male	41	45	86
Female	43	41	84
Prefer not to say	-	1	1
Total	84	87	171

The highest academic level group is over-represented, which can be explained mainly by the students. Danone employees provide more variety of education level in the sample (Table 8.3).

Table 8.3: The distribution of respondents by version and educational level. MBO represents senior secondary vocational education, and HBO represents higher vocational education. (Q4 - Section A.2)

N respondents	Version 1	Version 2	Total
Primary school	0	0	0
High school	2	0	2
MBO	0	1	1
HBO	11	10	21
University	70	76	146
Other	1	0	1
Total	84	87	171

The distribution of TU Delft students and Danone employees by faculty and department is shown in Figure 8.2. Lastly, the distribution of the respondents' age and their region of origin is shown in Table 8.5 and Table 8.4. The age distribution '0-18' was not present, and this can mainly be explained by the fact that the respondents represent students and employees who are mostly older than 18 years. Furthermore, the '18-25' generation over-represents the student data set, and the '26-35' generation over-represents the Danone data set. The Danone employees show more significant variability in age. The respondents were all based in the Netherlands, but they could come from different regions, from Europe or outside Europe.

Table 8.4: The distribution of respondents by version and region of origin, from or not from Europe. (Q2 - Section A.2)

N respondents	Version 1	Version 2	Total
From Europe	68	71	139
Not from Europe	16	16	32
Total	84	87	171

Table 8.5: The distribution of respondents by version and age group. (Q3- Section A.2)

N respondents	Version 1	Version 2	Total
18-25	33	31	64
26-35	27	36	63
36-45	16	15	31
46-55	5	4	9
56-66	3	1	4
Total	84	87	171

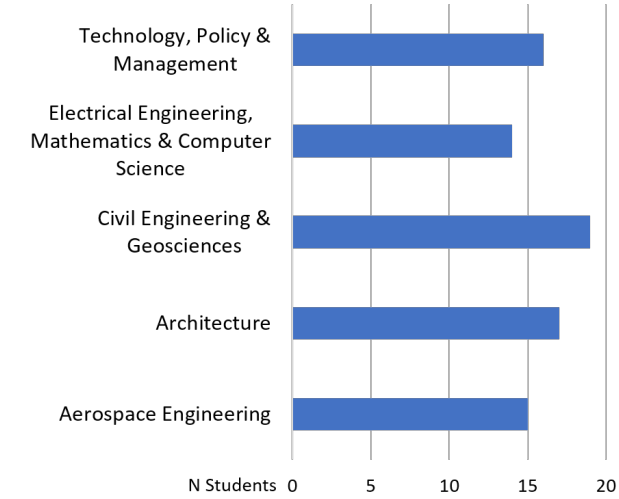
Based on the comparisons mentioned above, we can conclude that the samples for version 1 and version 2 represent the higher-educational level of Dutch society (CBS, 2018). On the other hand, more variability in age distribution is obtained by using Danone and TU Delft samples. People originate from Western and Southern Europe. For this research, we do not use the 'region of origin' to distinguish between data sets, as this is not part of the scope.

8.6.1 Allergies and medical food

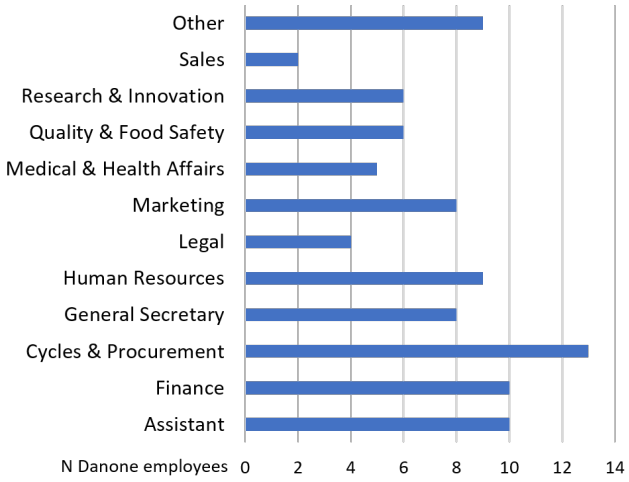
The distribution of respondents that require medical food and/or have an allergy is given in Table 8.6. Of the total sample, 14.62% of the respondents have a food allergy, and 5.85% of the respondents require medical food. This information will be used in the following section to study their specific perception.

Table 8.6: The distribution of respondents by version (V1 or V2), and allergies (A) or the need for medical food (MF). (Q6 Q7 - Section A.2)

N respondents	V1 Medical food	V2 Medical food	Total	V1 Allergies	V2 Allergies	Total
Yes	4	6	10	15	10	25
No	80	81	161	69	77	146
Total	84	87	171	81	87	146



(a) TU Delft students



(b) Danone employees

Figure 8.2: Distribution of respondents by TU Delft faculties and Danone departments. (Q5 - Section A.2)

8.7 RESULTS AND DATA ANALYSIS

This section shows the descriptive results of the survey data to answer the second (sub) research question, *What are the public perceptions and emotions towards GMMs?*. The emphasis and the order in this section relate to the propositions made in Chapter 7. The first eight propositions correspond to genetic engineering in general, while the remaining four propositions relate to GMMs specifically. Before the analysis, the data required to be transformed to numerical data to work further in SPSS (see Table A.1 and Table A.2). For some data we will refer to the appendix (Appendix A).

8.7.1 *A dichotomy is present – pro and con genetic engineering*

To study if a dichotomy is present with regards to genetic engineering, we asked the following open question, "What do you think when you hear about genetic engineering (max. 1 sentence)" (Q9 Section A.1). The respondents had the freedom to give detail on their first thoughts about genetic engineering. These answers were categorized by pre-specified labels: positive, negative, animals, and process. A concept map in Section A.4 summarizes the responses of the respondents. The frequency table in Table 8.7 presents the number of respondents that shared a neutral, positive, positive and negative, or adverse opinion. Positive statements towards genetic engineering are, for example, 'A brilliant discovery with a lot of potential for the future' or 'A more effective way of producing food.' In contrast, the more negative statements are, for example, 'Unnatural' or 'The unknown long term effects.' Examples of neutral ideas are "Manipulation of DNA' or 'GMOs.' In Section A.4, 30 statements are given that involved both positivity and negativity. These results imply that the opinions are not always polarized but that people also have combined positive and negative considerations.

Table 8.7: The distribution of respondents by version and neutral, positive and/or negative initial thoughts towards genetic engineering. (Q9 - Section A.2)

N respondents	Version 1	Version 2	Total
Positive	20	21	41
Negative	3	6	9
Positive and Negative	19	11	30
Neutral	42	49	91
Total	84	87	171

8.7.2 *The trust level of food companies is high*

The respondents were asked which information source they trust the most after providing the following sentence fragment: "With the help of genetic engineering, new compounds can be produced to make existing dairy products healthier and more nutritious" (Q12 in Section A.2). The distribution of selected answers by information source is shown in Table 8.8. It can be concluded that the trust level of food companies, famous people, and the government is low compared to universities and research groups.

Table 8.8: The distribution of selected answers (both versions 1 and 2) per specific information source that is trusted most. (Q12 - Section A.2)

Variable	N selected
Research Institutes	165
University	148
Government	64
Greenpeace or other environmental NGOs	59
Food companies	31
Social media	3
Famous people	1
Total	171

8.7.3 *Social media is the main information flow*

From the data in Table 8.9 it can be concluded that the most common information flows on genetic engineering are currently coming from social media or education. A large number of respondents have also chosen the 'Other' option. It remains to be unclear to which specific sources the 'Other' option relates to.

Table 8.9: The distribution of selected answers from most common information sources on genetic engineering (both versions 1 and 2) (Q10 - Section A.2).

Variable	N selected
Education	76
Social media	74
Other	66
Friends	44
Work	33
Events (e.g. conferences)	14
Total	171

8.7.4 *The perceived benefits outweigh the perceived risks*

The questionnaire helped to study the perception towards different statements on genetic engineering, which are addressed in Figure 8.3 and Table A.3. From this data, we can obtain that 57.1 % of the respondents strongly agree that genetic engineering benefits outweigh the risks. In addition, most respondents think that the food production processes can be made more sustainable (83.1 %) and do see the importance of investing in this technology (82.5 %). However, most respondents are not aware of the specific products made by genetic engineering (67.9 %). In addition, the public accepts the product more when a clear benefit is given (65.5 %). Later in this chapter, we tried to study the influence of specific benefits by using emotions and product-specific scenarios.

8.7.5 *The perceived risks to human health and the environment are deficient*

The respondents were asked if they think that genetic engineering is safe. In Table 8.10, the distribution of respondents is given, which implies that 57.90 % respondents do not know how safe genetic engineering is. Furthermore, few people do not think genetic engineering is safe (9.36 %), and other people do think genetic engineering is safe (32.75 %). To further explore their risk perception, the following questions were asked on a 6-point Likert-scale: To what extent do you think your body is at risk? And, to what extent do you think the environment is at risk? See Table 8.11 for the distribution of respondents. To conclude, 83 % of the respondents believe that the risk to human health is very mild to mild, while 70 % of the respondents believe that the risk to the environment is severe to moderate.

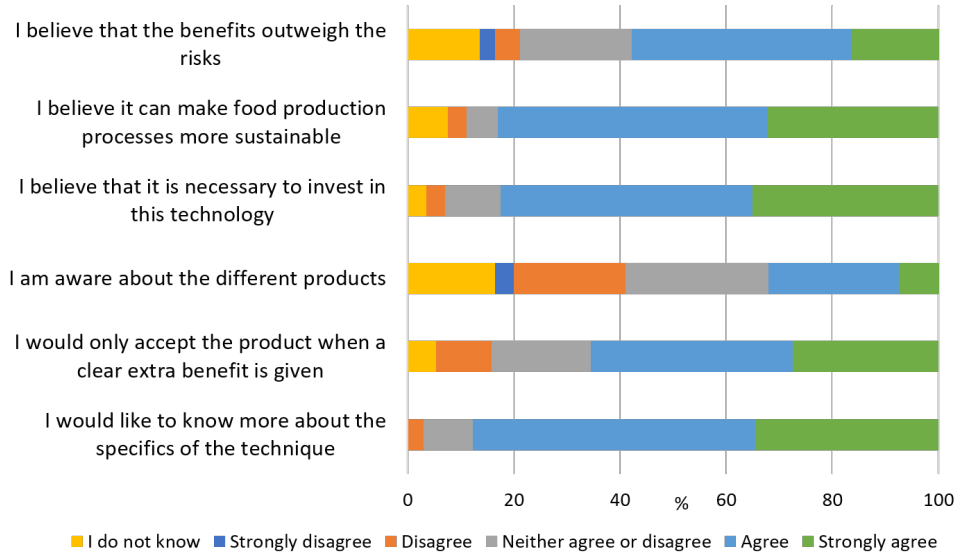


Figure 8.3: Stacked bar chart of the distribution of respondents per statement about genetic engineering in %. See Table A.3 for the corresponding frequency table. The last statement is specific to GMMs. (Q23 and Q25 - Section A.2)

Table 8.10: The distribution of respondents (both versions 1 and 2) that answer 'Yes, 'No,' 'I do not know' on the question: Do you think genetic engineering is safe? (Q21 - Section A.2)

Variable	N respondents
Yes	56
No	16
I do not know	99
Total	171

8.7.6 *Risk and benefit perceptions differ per generation*

The distribution of respondents per generation is given in Table 8.5. The number of respondents of the generation '46-55' and '56-65' was low and was therefore removed. The following null-hypothesis was tested, H_0: there is no difference between the generations. The Kruskal-Wallis H test was used to study a significant difference in risk and benefit perception towards genetic engineering by generation. First, the Levene's test showed that the distributions of the different age groups were of similar shape (p-value > .05 Table A.4). A Kruskal-Wallis H test showed no significant difference in score between the three different generations and their answer to questions related to the risk (Q21 and Q22). The results can be found in Section A.8.

Table 8.11: The distribution of respondents (both versions 1 and 2) of answers to the questions about the level of risk to the human body and environment on a 6-point Likert-scale. (Q22 - Section A.2)

Variable	Human health	Environment
Very mild	31	20
Mild	52	35
Neutral	27	26
Moderate	32	47
Severe	4	23
I do not know	25	20
Total	171	171

8.7.7 *Low awareness results in a higher level of concern*

The awareness was measured by the familiarity with genetic engineering. The distribution of respondents that are familiar or non-familiar with genetic engineering can be found in Table 8.12. The following null-hypothesis has been tested, H_0: low awareness does not result in a higher level of concern. The Mann-Whitney U test was chosen to test significant differences between the two independent groups, familiar or not familiar, and the ordinal data from Q24 on level of concern (Table 8.13). Prior to the Mann-Whitney U test, Levene's test was performed to determine the shape similarity of the distributions. In Table A.4, the results (p-value .014 < .05) can be found, and it can be concluded that the null-hypothesis, H_0: the shapes are identical, should be withdrawn. This means that the conclusions from the Mann-Withney U test should come from the difference in mean ranks. By using the results of the mean ranks of the Mann-Whitney U test in Table A.8, it can be concluded that the level of concern in the non-familiar group was significantly higher than the familiar group (U = 2989, p = .044). This result implies that being more familiar with genetic engineering results in being less concerned about genetic engineering. The Spearman's rho test measures the correlation between the level of concern and familiarity, and the results can be found in Table A.5. There was a low significant positive correlation between level of concern (1 = Very concerned to 5 = very unconcerned) and familiarity, $r_s(169) = .155$, $p < .044$. For more information on the specific questions, see Section A.2.

Table 8.12: The distribution of respondents (both versions 1 and 2) being or not being familiar with genetic engineering. (Q7 - Section A.2)

Variable	N Respondents
Yes	94
No	77
Total	171

Table 8.13: The distribution of respondents (both versions 1 and 2) by level of concern towards genetic engineering on a 6-point Likert scale. (Q24 - Section A.2)

Variable	N respondents
Very unconcerned	21
Somewhat unconcerned	44
Neither concerned nor unconcerned	42
Somewhat concerned	49
Very concerned	9
I do not know	6
Total	171

Table 8.14: The Mann-Whitney U ranks and test statistics with independent grouping variable familiarity (yes/no) with genetic engineering and the ordinal responses to Q24 about level of concern towards genetic engineering. (Q24 - Section A.2

Familiar	N	Mean Rank	Sum of Ranks	Test	Q24
Yes	94	79.30	7454.00	Mann-Whitney U	2989.000
No	44	94.18	7252.00	Wilcoxon W	7454.000
Total	171			Z	-2.015
				Asymp.Sig.(2-tailed)	.044

8.7.8 *The type of consumer affects the more positive attitude towards genetic engineering*

To draw more specific conclusions on the type of consumer, we study the influence of (a) medical food requirements, and (b) food allergies on the answers to Q13 and Q23 (Table 8.15 and Table A.3). In Q13, the emotional responses to genetic engineering were measured on a 6-point Likert-scale. The outcomes of Q13 are shown in Table 8.15 and Figure A.4. This data correspond to the gut feelings response of the respondents to genetic engineering. No detailed information on product-specific scenarios was provided yet. From the data in Table 8.15, it can be concluded that the emotions interest, hope, and happiness are felt the strongest.

Medical food and allergy

The independent groups, medical food (yes/no) and allergy (yes/no), were used in the Mann-Whitney U test together with the ordinal data from Q13 (Table 8.15) and Q23 (Table A.3). First, Levene's test was performed to determine the shape similarity of the distributions. In Table A.4, the results can be found, and it can be concluded that the null-hypothesis, H_0: the shapes are identical, should not be withdrawn. This means that the conclusions from the Mann-Withney U test should come from the difference in medians and not from mean ranks. The Mann-Whitney U test results in Table A.8 have a p-value < .05 for Q23.2 and Q23.5. These results show that the people who need medical food are more positive towards investing in genetic engineering (p = .013, median = 4.00). Secondly, in comparison to the rest of the sample, they strongly value that the GM product must deliver a specific benefit for them (p = .030, median = 4.00). The latter also holds for the people who have an allergy (p = .042, median = 4.00). For more information on the specific questions, see Section A.2. The other statements in Q23 were not found

to be significantly different for the medical food and allergies groups as opposed to the rest of the sample (Table A.9). Lastly, the impact on the emotions in Q13 was not found to be significantly different from the rest of the sample.

Table 8.15: The distribution of % (both versions 1 and 2) of degree of emotional responses to Q13 on a 6-point Likert-scale. (Q13 - Section A.2)

N=171, values in %	Interest	Surprise	Fear	Anger	Joy
1 (Weak)	0.6	17.0	12.3	38.6	9.9
2 (Slightly weak)	2.9	14.0	16.4	9.9	10.5
3 (Neutral)	8.8	36.8	27.5	17.5	42.1
4 (Slightly strong)	44.4	12.9	29.2	6.4	15.8
5 (Strong)	43.3	4.7	9.4	1.2	3.5
6 (Does not apply)	0	14.6	5.3	26.3	18.1
Total	100	100	100	100	100
Mean (Scores 1-6)	4.27	3.18	3.23	3.01	3.47
Std. Deviation	0.788	1.560	1.324	2.036	1.492
N=171, values in %	**Disgust**	**Hope**	**Irritation**	**Happiness**	**Powerlessness**
1 (Weak)	31.6	2.9	33.3	7.6	24.0
2 (Slightly weak)	15.2	5.8	13.5	11.1	9.9
3 (Neutral)	21.6	19.3	21.6	42.1	24.0
4 (Slightly strong)	8.2	35.1	5.3	13.5	15.2
5 (Strong)	0.6	28.7	1.2	5.8	5.8
6 (Does not apply)	22.8	8.2	25.1	19.9	21.1
Total	100	100	100	100	100
Mean (Scores 1-6)	2.99	4.05	3.03	3.59	3.32
Std. Deviation	1.896	1.144	1.963	1.498	1.804

8.7.9 *The acceptance would be more significant for GMMs than for GMPs and GMAs*

The data in Table 8.16 indicate that genetic engineering on micro-organisms (46.20 %) is more accepted than on plants (30.41 %) and animals (15.20 %). The remaining people do not care (8.19 %). This outcome is mainly related to the perceived possible risks, which can be concluded from Table 8.17. On the second and third place, naturalness (closer to humans) and sustainability. The option 'Other' is selected 19 times, but it remains to be unclear as to which specific reasons the 'Other' option relates to. In the first section of the online survey, the respondents were asked about their knowledge of micro-organisms (Table 8.18). With the Mann-Whitney U test, the impact of this independent variable is measured on the outcome of Q15 (most acceptable organism to perform genetic engineering on), which was put on an ordinal scale. The test resulted in a p-value > .05 for all organisms. Hence, the prior knowledge of micro-organisms does not affect the outcome of Q15. The results can be found in Section A.9.

Table 8.16: The distribution of respondents (both versions 1 and 2) of most acceptable organism to perform genetic engineering on. (Q15 - Section A.2)

Variable	N respondents
Micro-organisms	79
Plants	52
Animals	26
I do not care	14
Total	171

Table 8.17: The distribution of respondents (both versions 1 and 2) to determine choice of Q16. (Q16 - Section A.2)

Variable	N respondents
Possible risks	94
Closer to humans	36
Other	22
Sustainability	19
Total	171

Table 8.18: The distribution of respondents (both versions 1 and 2) that know and do not know micro-organisms. (Q11 - Section A.2)

Variable	N respondents
Yes	158
No	13
Total	171

8.7.10 *The public is ready to learn more*

From Figure 8.3 and Table A.3, it can be concluded that 87.7 % of the respondents agree or strongly agree with the following statement: I would like to know more about the specifics of the technique. The Kruskal-Wallis H test was performed to study if there is any significant difference between the age groups, '18-25', '26-35', and '36-45' (see Section A.8). For the Levene test results, see Section 8.7.6. The significance value is $.500 > .05$, which implies that there is no difference between the age groups. All generation groups do see the importance of education on GMMs.

8.7.11 *The type of product (e.g., general food product or medical food product) affects the positive and negative emotions*

Both questionnaire versions first describe a general dairy-based product, such as yogurt, which is produced by GMMs in a contained environment. The next product in the questionnaire is produced in the same way, but the purpose is different for each version. In version 1, the reader is put in the position of a parent who needs to buy a GMM product where the alternative production is unethical, such as baby milk. In version 2, the reader is put in the position of a patient in need of a medical GMM product. For this research, we are interested in the emotional responses towards these different types of products to make comparisons between them. See Q17 and Q19 in Section A.2 for the descriptions of the GMM dairy-based products.

In particular, we look at the change of emotional response between the general product and special product on a 6-point Likert-scale. For both versions, see Figure A.3 for the stacked bar charts, and Table 8.19 and Table 8.20 for the frequency tables. The respondents answered the 6-point Likert-scale questions on emotions after having read the product-specific scenarios. After each product-specific scenario and its respective questions, an open question was asked if they felt any other emotion. The respondents were not required to provide an answer. The answers varied from the more positive (curious, grateful, admiration, reluctant) to the more negative (uncomfortable, fear of missing out, annoyance, concern, afraid, worried).

To draw conclusions on the change of emotions towards the special products, the responses 'does not apply' and 'neutral', were ignored. From the outcome of version 1 (Table 8.19), it can be concluded that the following emotions show a stronger emotional response (stronger and slightly stronger versus weaker and slightly weaker in %): interest (69 % > 7.2 %), joy (57.1 % > 14.3 %), surprise (25 % > 10.8 %), hope (51.2 % > 6 %), and happiness (25 % > 8.3 %). The following emotions show a weaker emotional response (stronger and slightly stronger versus weaker and slightly weaker in %): fear (26.2 % < 31.2 %), irritation (7.2 % < 33.3 %), and anger (6 % < 35.7 %). The change in emotional response of disgust (35.7 % > 33.4 %) and powerlessness (27.4 % > 25%) do not differ much. To conclude, the positive emotions do increase for the special product in version 1, baby milk, while the more negative emotions, fear, irritation, and anger decrease.

Table 8.19: The distribution of % (Version 1) of degree of emotional responses to Q20 on a 6-point Likert-scale. (Q20 - Section A.2

N=84, values in %	Fear	Interest	Surprise	Joy	Disgust
1 (Weaker)	16.7	2.4	4.8	2.4	16.7
2 (Slightly weaker)	15.5	4.8	6.0	11.9	16.7
3 (Neutral)	29.8	20.2	45.2	36.9	32.1
4 (Slightly stronger)	22.6	46.4	20.2	20.2	3.6
5 (Stronger)	3.6	22.6	4.8	7.1	0
6 (Does not apply)	11.9	3.6	19.0	21.4	31.0
Total	100	100	100	100	100
Mean (Scores 1-6)	3.17	3.93	3.71	3.82	3.46
Std. Deviation	1.504	0.991	1.367	1.407	1.866
N=84, values in %	**Hope**	**Irritation**	**Happiness**	**Powerlessness**	**Anger**
1 (Weaker)	1.2	22.6	1.2	11.9	20.2
2 (Slightly weaker)	4.8	10.7	7.1	13.1	15.5
3 (Neutral)	33.3	28.6	47.6	33.3	27.4
4 (Slightly stronger)	36.9	4.8	17.9	14.3	6.0
5 (Stronger)	14.3	2.4	7.1	1.2	0
6 (Does not apply)	9.5	31.0	19.0	26.2	31.0
Total	100	100	100	100	100
Mean (Scores 1-6)	3.87	3.46	3.80	3.58	3.43
Std. Deviation	1.073	1.942	1.297	1.688	1.916

The outcome of the special product in version 2 can be found in Figure A.3 and Table 8.20. To draw conclusions on the change of emotions, the responses 'does not apply' and 'neutral', were ignored. It can be concluded that the following emotions

show a stronger emotional response (stronger and slightly stronger in % versus weaker and slightly weaker in %): interest (87.4 % > 1.1 %), surprise (37 % > 8 %), joy (72.9 % > 2.2 %), hope (86.2 % > 1.1 %), and happiness (71.3 % > 3.4 %). The following emotions show a weaker emotional response (stronger and slightly stronger versus weaker and slightly weaker in %): fear (12.6 % < 42 %), disgust (2.3 % < 36.7 %), irritation (4.5 % < 35.6 %), powerlessness (8 % < 26.4 %), and anger (3.4 % < 28.7 %). To conclude, the positive emotions are felt stronger for the special product in version 2, medical product, while the more negative emotions, decrease.

Table 8.20: The distribution of % (Version 2) of degree of emotional responses to Q20 on a 6-point Likert-scale. (Q20 - Section A.2)

N=87, values in %	Fear	Interest	Surprise	Joy	Disgust
1 (Weaker)	23.0	0	4.6	1.1	26.4
2 (Slightly weaker)	19.5	1.1	3.4	1.1	10.3
3 (Neutral)	24.1	9.2	27.6	12.6	20.7
4 (Slightly stronger)	11.5	20.7	32.2	27.6	2.3
5 (Stronger)	1.1	66.7	4.8	48.3	0
6 (Does not apply)	20.7	2.3	19.0	9.2	40.2
Total	100	100	100	100	100
Mean (Scores 1-6)	3.10	4.60	3.98	4.48	3.60
Std. Deviation	1.779	0.739	1.257	0.951	2.121
N=87, values in %	**Hope**	**Irritation**	**Happiness**	**Powerlessness**	**Anger**
1 (Weaker)	0	26.4	2.3	16.1	24.1
2 (Slightly weaker)	1.1	9.2	1.1	10.3	4.6
3 (Neutral)	6.9	18.4	16.1	26.4	18.4
4 (Slightly stronger)	33.3	3.4	27.6	5.7	3.4
5 (Stronger)	52.9	1.1	43.7	2.3	0
6 (Does not apply)	5.7	41.4	9.2	39.1	49.4
Total	100	100	100	100	100
Mean (Scores 1-6)	4.55	3.68	4.37	3.85	3.99
Std. Deviation	0.759	2.132	1.047	1.932	2.138

8.7.12 *The emotions are linked to benefits, awareness, and trust.*

The GMM produced yogurt, general product scenario, is for both versions the same. After this general-product scenario description, the respondents were asked to select the statements that best fit the respective emotion (positive or negative). The following ten emotions were studied: interest, surprise, joy, hope, happiness, fear, disgust, irritation, powerlessness, and anger. The statements correspond to particular antecedents of emotions (Figure 8.4), which were discussed to be possibly relevant from the expert interviews and Chapter 6. From the data in Table 8.21 and Table 8.22, it can be concluded that the answer, 'I do not feel this emotion,' over-represents the data set (threshold > 50 %). In the following chapter, we discuss the influence of this result, and we evaluate the questionnaire method.
To draw conclusions on these results, the selected answers of 'I do not feel this emotion', are ignored. The following observations were made with the results from Table 8.21 and Table 8.22. On the next page, the emotions are ranked from most to least felt, and the three most selected antecedents of emotions are presented.

Antecedents of emotions	Positive statements	Negative statements
Naturalness	The process or product is new and exciting	The process or product is unnatural
Risks/benefits	The risks are worth the benefits	The risks are not worth the benefits
Fairness	The risks are fair to all	The risks are not fair to some
Awareness	I am confident this is well-researched and understood	There are many unknowns
Trustworthiness	I trust the companies or institutions involved in this	I do not think this process can be trusted to certain companies or institutions
Autonomy	People will be given opportunities to choose this or not	People may not have a choice about this

Figure 8.4: The positive and negative statements used in the questionnaire to study the respective antecedents of emotions. (Q17 and Q18 - Section A.2)

1. Interest - Novelty (naturalness) (53.8 %) > Awareness (36.3 %) > Autonomy (24.6 %)
2. Hope - Novelty (naturalness) (43.9 %) > Awareness (24.0 %) > Risks/benefits (22.2 %)
3. Fear - Awareness (31.0 %) > Trustworthiness (28.7 %) > Autonomy (22.8 %)
4. Joy - Novelty (naturalness) (29.2 %) > Awareness (13.5 %) > Risks/benefits (11.1 %)
5. Anger - Naturalness (28.1 %) > Risks/benefits (14.0%) = Awareness = (14.0 %)
6. Disgust - Autonomy (25.7 %) > Awareness (15.8 %) > Trustworthiness (9.9 %)
7. Happiness - Novelty (naturalness) (27.5 %) > Other (4.1 %) > Autonomy (3.5 %)
8. Irritation - Trustworthiness (8.2 %) = Autonomy (8.2 %) > Awareness (7.0 %)
9. Surprise - Novelty (naturalness) (9.4 %) > Awareness (8.8 %) > Trustworthiness (6.4 %)
10. Powerlessness - Autonomy (6.4 %) > Awareness (5.3 %) > Trustworthiness (4.7 %)

It can be concluded that the emotions interest, hope, and fear have been felt the most since the value of 'I do not feel this emotion' was the smallest in comparison with the other emotions (threshold: < 50 %). The positive emotions, interest, and hope point to the antecedents of emotions: novelty, awareness, autonomy, and risks/benefits. The negative emotion, fear, points to the antecedents of emotions: awareness, trustworthiness, and autonomy. Awareness and autonomy results to be important for the experience of all three emotions. Some respondents experience positive emotions because they think that the technique is well-researched and understood, while others experience fear because of the many unknowns. The fact that the GMM product is new and exciting creates positivity, which could

stimulate acceptance. Especially once it is clear that the perceived benefits outweigh the perceived risks, however, these results imply that it is important to think about autonomy. People experience positivity when they are given opportunities to choose a certain product. Once people do not feel they have a choice and the trust is low, negative emotions such as fear and disgust may arise. The negative emotion, anger, is a strong emotion but is not felt the most. It can be concluded that anger points mostly to the concept of naturalness. This ethical concern has already been studied by multiple research groups. However, since anger is not felt the most, naturalness would not be the main ethical concern to focus on. The public seems to be interested in this novel product, which does not follow the principles of naturality. Most people are actually interested because of the excitement and have the confidence that it is well understood. However, the emotion fear is close to these positive emotions and could arise from low awareness, low benefits, and zero autonomy.

Table 8.21: The distribution of selected answers (both versions 1 and 2) of concerns to the positive emotions interest, surprise, joy, hope, and happiness. 1 = I do not feel this emotion, 2 = The process or product is new and exciting, 3 = The risks are worth the benefits, 4 = The risks are fair to all, 5 = I am confident this is well-researched and understood, 6 = I trust the companies or institutions involved in this, 7 = People will be given opportunities to choose this or not, and 8 = Other. (Q17 - Section A.2)

N=171, values in %	**Interest**	**Surprise**	**Joy**	**Hope**	**Happiness**
1	8.8	79.5	50.3	24.6	64.3
2	53.8	9.4	29.2	43.9	27.5
3	20.5	1.8	11.1	22.2	1.8
4	4.1	2.9	1.8	2.9	1.2
5	36.3	8.8	13.5	24.0	2.3
6	12.9	6.4	4.1	8.2	.6
7	24.6	4.1	6.4	14.6	3.5
8	7.0	1.2	5.8	7.0	4.1
Total	100	100	100	100	100

Table 8.22: The distribution of selected answers (both versions 1 and 2) of concerns to the negative emotions fear, disgust, irritation, powerlessness, and anger. 1 = I do not feel this emotion, 2 = The process or product is unnatural, 3 = The risks are not worth the benefits, 4 = The risks are not fair to some, 5 = There are many unknowns, 6 = I do not think this process can be trusted to certain companies or institutions, 7 = People may not have a choice about this, and 8 = Other. (Q18 - Section A.2)

N=171, values in %	Fear	Disgust	Irritation	Powerlessness	Anger
1	42.1	59.6	76.6	84.2	54.4
2	15.8	4.7	5.8	2.9	28.1
3	4.7	1.8	2.9	1.2	14.0
4	3.5	2.9	3.5	1.8	4.1
5	31.0	15.8	7.0	5.3	14.0
6	28.7	9.9	8.2	4.7	8.2
7	22.8	25.7	8.2	6.4	9.4
8	1.8	1.8	1.2	2.3	1.2
Total	00	100	100	100	100

8.8 CONCLUSION

The scope of this chapter was to answer the second (sub) research question on the public perceptions, emotions, and underlying ethical concerns. The qualitative results imply that people are not firmly for or against genetic engineering. In contrast, the perceptions were found to be positive, neutral, or both positive and negative. A minor group felt only negative. From the quantitative results, it can be concluded that the majority of the public was interested and hopeful in genetic engineering and GMMs specifically. The opinion towards GMMs was discovered with the help of product-specific scenarios to bring light to emotions. The novel features of the technique, such as getting new benefits to dairy-based products bring positivity. The emotions interest and hope overrule the more negative emotions such as fear and anger. Furthermore, it was found that the public accepts genetic engineering more when applied to micro-organisms instead of plants or animals. However, certain conditions must be met to avoid the rise of common ethical concerns found in previous debates about GM crops and animals. The emotions link to awareness, trustworthiness, and autonomy to be essential for product acceptance. As described in Chapter 6, awareness and trustworthiness are strongly related. However, the experts are doubtful about the level of information that should be spread on this technique. Hence, further discussion on trustworthiness and awareness is present in the following chapter.

For GMAs and GMPs, the naturalness of the technique was found to be essential for product acceptance. However, for GMM dairy-based products, it seems that this ethical concern is not the most critical. To provide solutions for patients and others that require special medical food, is what people are interested in. The positive emotions were felt stronger, and the negative ones were felt weaker towards these special types of products (version 1 and version 2) instead of the general product, yogurt. The public would accept the technology more when it can bring something to society by adding value to a product or creating a valuable product that does not exist in nature. This result is in line with what research groups found

for purely pharmaceutical products. However, the food companies need to build trust by, for example, collaboration with research institutes and universities. And at the same time giving people the chance to choose between products to facilitate the transition. Apart from these positive conclusions on this technique, there were also people negative about genetic engineering and GMMs. As the experts also mentioned, there will always be extreme cases. It is essential how much pressure they can perform on biotech and what the impact would be. In this study, the numbers of these extremely negative cases were found to be low (Table 8.7). However, food companies should be careful about the environmental NGOs and controversial groups that might arise. As the experts expected, the trust level towards these pressure groups is high compared to the food companies for all generations.

The questionnaire created lots of interest by the respondents, and positive reactions towards the questionnaire format were created. The following chapter will give more information on the discussion of the questionnaire results and the questionnaire method. Furthermore, the descriptive results will be discussed, and experts' and laypeople's opinions will be compared.

9 RESULTS AND DISCUSSION

This chapter discusses the results of the semi-structured interviews with experts (Chapter 7) and the questionnaire results with laypeople (Chapter 8). With the help of this chapter, we will answer the last (sub) research question, *How do we evaluate the ethical concerns, which include perceptions and emotions?* This question is answered in the following two sections: (1) an evaluation of the results (Section 9.1), and (2) an evaluation of the research methods (Section 9.3).

9.1 RESULTS EVALUATION

The evaluation of the results is divided into the following sub-sections, where we discuss the most interesting or remarkable findings.

9.1.1 Type of organism

From the findings of this research, it was concluded that it is essential to look differently at the ethical concerns of GMMs versus other GMOs. From the interview data, it seems that it is a moral question case-by-case, which implies that it is essential to look at specific products, targeted consumers, and their feelings that belong to them. Hence, the second part of this research focuses on specific product scenarios. The conclusions on emotions and GMM products are therefore limited to these specific scenarios. The scenarios are focused on the dairy-based industry, value-added health products, no GMO in the final product, and GMMs in a contained environment. New scenarios must be created to know the emotions and perceptions towards other types of GMM products. For example, products containing GMO material in the final product or GMM products that are deliberately released (e.g., strains). In addition, according to the expert's opinions, the exact type of organism would also matter. With the help of the questionnaire, it was found that the public accepts genetic engineering more when applied to micro-organisms instead of plants or animals. This difference could be explained due to factors such as the perceived risks, closer to humans, sustainability, or other reasons. From the results of this research, it was found that the distinction between GMOs is because of the lower perceived risks. It was expected that naturalness (closer to humans) would play a more significant role. We will discuss the findings on naturalness further in Section 9.2. The 'Other' option was added to determine other reasons on how the public bases this distinction. However, no conclusions could be drawn since there was no possibility to write freely on this selected answer. Interviews with the public could give more knowledge on other reasons for accepting genetic engineering on micro-organisms more than other GMOs.

9.1.2 Trust and awarenesss

Apart from the opinion to look at concerns on a case-by-case basis, the social sciences experts address that trust in companies and institutions is at the root of acceptance. The link between trust, and awareness, was found to be important in literature (Chapter 6). The questionnaire results also show that a low awareness results in a higher level of concern. However, the experts showed their concern on the level of information on genetic engineering and its specific framing. When providing more information on genetic engineering, people can make an easy shortcut to previous events on genetic engineering that involve negative emotions. These shortcuts at earlier events were also found in the questionnaire results by concepts such as 'Dolly the sheep,' 'Cloned fetus,' and 'Stier Herman'. These are all examples of people feeling uncomfortable about GMOs and bad management of their implementation. However, the number of people who give these negative responses is low for this sample. And, it seems that the public is ready to learn more and is willing to invest in this technology.

The spread of the information and the education would be complex for big dairy-based companies such as Danone. In contradiction to the experts' propositions on trust, the level of confidence in food companies was low. The environmental NGOs, universities, and research institutes show a better confidence level. Especially environmental NGOs could start the fire on these products, and the whole biotech industry would be affected by it. However, once you start attacking enzymes and vitamins being produced in a contained environment, everything made by fermentation would be under attack. Therefore it is essential to clarify the difference between GMMs that are deliberately released and belonging to another regulation. Hence, food companies should educate and be transparent but use the sources that are trusted most. As expected, social media was found to be the main information flow on genetic engineering. However, the respondents do not seem to trust social media. It would have been problematic once social media would be trusted most since information comes from various sources. As the social sciences experts stressed, for future GMM implementations, it is essential who is providing the information, how much, and what language is used. Where communication experts and companies stress that it is impossible to educate, scientists show their interest in education. So, there is the political importance of giving people the freedom to choose by being transparent. However, we cannot expect people to decide as experts because of their different understanding of the risks and the studies that have been carried out.

9.2 TYPE OF PRODUCT

As expected from the interviews, the emotions were affected by the type of products presented in the questionnaire. For this research, we compared a general dairy-based product and two special dairy-based products. The special dairy-based products were a medical dairy-based food product that cannot be found in nature and a medical dairy-based food product where the natural alternative is unethical. This research found that most perceptions and emotions towards these GMM

special products were more positive than for general food products produced by GMMs. The results showed that most of the public is ready to accept genetic engineering and GMM products, specifically when a clear benefit is given. Before the questionnaire results, we expected that these special dairy-based products would have a higher acceptance level than the general dairy-based product. This hypothesis was made due to Roesers' (2018) work on the status quo and the literature on genetic engineering for pharmaceutical production, and this aligns with our outcome (Frewer et al., 1995). The special (medical) product resulted in stronger positive emotions and weaker negative emotions. Previous research groups like Frewer et al. (1995) discuss the difference in perception towards pharmaceutical and food products. People tend to accept more when genetic engineering is used to make pharmaceuticals. Following Roeser (2018), this has to do with the status-quo. People tend to be more against genetic engineering because of the conservative status quo; they prefer naturalness and are afraid of risks from new technologies. The medical dairy-based product has the best-case scenario - that people become healthier because of this product. The other dairy-based product replaces other existing processes, which can be considered unethical. These two products help to override the status-quo bias. However, people could be against this product because of intrinsic values following deontology (e.g., naturalness). From the results of this research, naturalness does not seem to be the primary concern. The majority of the respondents felt optimistic about GMMs by hope and interest. However, negativity can arise when there is unclarity about risks and worry about autonomy. On the contrary, as the social sciences experts stressed, there will always be people against a particular technology. These groups form essential target groups for future GMM research on product acceptance in the dairy-based industry. The responses of these groups are of interest since they could point to fundamental ethical concerns. For our highly educated sample, we had minor negative reactions. From the data on the first questions, it was determined that these respondents were not familiar with genetic engineering. They also replied in the open question that they had no idea about the technology or referred it to 'Dolly the sheep' or 'Stier Herman' or 'Cloning babies'. From the other sections in the questionnaire, these groups were found to have more negative emotions. These negative emotions, such as disgust and anger, point to ethical concerns related to the conservative quo - naturalness. In this research, naturalness, and GMMs have not been studied extensively. In literature, this concept has already widely been studied, and the difficulty here is the definition people give to naturalness. Naturalness is something intuitive, and the consumer links naturalness with good or pure. However, there are many examples in nature that are not suitable for human health. The experts hypothesize that the public would like to go back to natural, to diverse, to wild crops, which is not a solution for 9 billion people on the globe. The discussion on naturalness and playing god has already been there from the moment humanity discovered DNA. These thoughts hold the same for the risks, and it continues to be necessary from the experts' point of view. However, this research showed that naturalness might not become the main issue for GMM product acceptance. There is a need to talk more about the deeper emotions towards the technologies' potentials and reach sustainability goals.

Organic

Dairy-based companies started introducing organic products. However, GMMs and organic products form a problem. Organic farming is a form of agriculture that does not permit the use of genetic engineering. The organic way of producing food and organic food products is more natural than conventional farming, both by producers and consumers. Better knowledge of the arguments used in organic farming might be necessary to understand the intrinsic public concerns about GMM, especially in connection with food.

9.2.1 Laypeople and experts

The semi-structured interviews helped to understand the experts' position towards GMMs specifically better. The questionnaire was distributed afterwards to study laypeople's opinions and to compare experts and laypeople. From this research, we can conclude that the groups under study are interested in GMMs. Both groups would like GMM products to be developed ethically and responsibly. However, the product needs to have a clear benefit, and the risks should be managed. Even the technical experts are afraid and feel uncomfortable while working with the technology because of what it can do to the environment. The fear of this technology can open our eyes to risks that we may not otherwise be sensitive to (Roeser, 2018). This research concluded that people perceive the risks to be more severe for the environment than for the human body, while actually, most people do not know about the dangers of GMMs.

From the results on emotions, we found that laypeople felt hope and interest to a more substantial degree than the emotion fear. However, technical experts express their fears and this leads to being ethically responsible for the choice of product implementation. They prefer working on GMMs in a contained environment to produce special health products over products with living cultures to copy products that we can already find from nature. The experts are also not ready to find GMO-containing products on the market. For now, GMM products should be well-purified to avoid the spread of living cultures into the environment. It is interesting to note that the experts expressed some fear even though the questions for them were not as focused on emotions as the survey questions to laypeople.

The regulations seem to be behind, and exciting innovations that have low risk are slowed down. On a case-by-case basis, the opinions seem to be different, and the acceptance does not seem to be a significant problem for this type of genetic engineering; contained environment with micro-organisms. For this future debate, it is not really about laypeople and experts. And, it is not really about pro-GMM people and against-GMM people. The perceptions towards this technology do not seem to be completely polarized. From this research, we can carefully say that people are pretty positive with some underlying concerns to which the emotions are linked, such as trust, awareness, benefit, and autonomy. The negative emotions will increase, and the positive emotions will decrease when these concerns are not taken seriously. Then people will develop strong pro and con positions towards GMMs.

9.2.2 Extreme groups

The respondents in need of medical food and allergies were significantly more favorable towards investing in genetic engineering. However, they also strongly value the benefits it should give and the risks that are involved. This argument could be linked to their awareness of food processes. These groups of people have to be busier with their food patterns and how their food is produced. They, therefore, already have a clearer understanding of how these technological food processes work. For this reason, these groups can form a more explicit opinion on genetic engineering if it is applied in a good or bad way. These people require GMM products and want to invest more because they know the opportunities. The other people do not understand these processes yet, and for them, it is a black box when talking about genetic engineering. They do not know how this technology should help them.

9.2.3 Risky and disruptive technologies

Disruptive and risky technologies have this kind of intrinsic connection, where the risks are closely connected to the introduction of a technology. Technologies such as genetic engineering can reduce risks but also introduce new ones. The questionnaire in Section A.2 was used to compare experts' and laypeople's perceptions and helped to look for new ethical concerns. In this way, we avoid claiming conservative reactions that are expected, but we also bring light to new ones. For GMMs, specifically, we talk about controversies that are not necessarily there yet. Experts stress that the current debates on ethical concerns go more about GMOs as a whole. This research tries to particularly study the new risks that would come with the introduction of GMMs. It stresses the need for case-by-case analysis and that GMMs are not perceived as very risky or unnatural by the sample of this study. Therefore, we can carefully say that the public is less concerned about GMMs, as policy-makers may expect. We drew these conclusions with the help of this research, where we tried to understand how emotions are likely to show up. It becomes more apparent that this topic on genetic engineering and its risk assessment include more facets than only a CBA. Another approach, such as Roesers' (2018), is needed to treat all issues or do justice to their complexity and inter-relatedness.

9.3 QUESTIONNAIRE METHOD

With this research, we explored using an online questionnaire to study the emotions and perceptions towards GMMs. The product-specific scenarios were created and helped to stimulate the respondents' gut feelings towards future dairy-based GMM products. Three things can be said on the questionnaire approach: (1) sample validity, (2) I do not feel the emotion, and (3) the lack of interaction.

9.3.1 Sample validity

The purpose of this research was to study laypeople's opinions towards genetic engineering and GMMs. Because of confidentiality reasons, the study area was limited to Danone and the Delft University of Technology. People with a higher academic degree than the average Dutch citizen over-represented the sample because of this selected study area. The overall results of the questionnaire were positive on the development and implementation of genetic engineering and future GMM products. However, people with lower academic background could give different responses since familiarity and awareness about the technique has been identified to affect the level of concern (Riddell and Song, 2017). Another discussion point is that we should have asked the Danone respondents for their educational degree next to the department. The Danone employees who studied biotechnology-related studies should have been excluded from the sample. In addition, Danone employees might be biased since the questionnaire was distributed from the researcher's Danone intern position. As a result, the questionnaire could be made with a more positive feeling since it is linked to Danone. The question is whether these employees represent the general public. However, it was still chosen to distribute the questionnaire among TU Delft students and Danone employees because of the following points. Firstly, the Danone experts felt that there was already a difference in opinion amongst Danone's top level management on this topic. Secondly, the Danone sample provided more variability in age distribution. The integration of the older generation was vital since it was expected that, the older generation might have a stronger opinion towards the technology. Thirdly, the departments, such as finance and legal, were asked to participate in this technology that do not have biotechnology-related knowledge. However, the conclusions drawn on the results of this study should be taken with caution, especially when making generalizations to laypeople.

9.3.2 Method to study emotions

One of the answers to the questionnaire's multiple-choice questions was 'I do not feel this emotion'. As illustrated in Table 8.21 and Table 8.22, the respondents selected the option 'I do not feel this emotion' in large numbers. The question, therefore, arises whether this method is the most suitable method to study gut feelings and deep emotions. Hence, we must take the conclusions on the answers to Q17 and Q18 with caution. It could have been challenging for the respondents to think about their emotions. Or the respondents might have lost concentration at the end of the questionnaire. Hence, the results of Q17 and Q18 can only indicate the link between emotions and respective antecedents of emotions. The responses on Q20, on the other hand, required Likert-scale answering from weaker to stronger and did not give a low response rate. These results and conclusions on Q20 are therefore more reliable.

9.3.3 The lack of interaction

A more interactive way, such as focus groups, could help learn about emotions and reactions to others. The interaction and the influence of other people could create different and non-expected emotional responses. Social media was found to be the primary information source of genetic engineering, while interestingly, their trust level in social media is low. Social media uses people's interactions on various topics, and others can easily influence people's opinions. It would, therefore, be interesting how different people react to each other and how emotions are formed and affected. These essential interactions were lacking in the questionnaire method. The emotions were studied by individuals who were not in the middle of a discussion with more stakeholders.

9.4 OTHER DISCUSSION POINTS

Antecedents of emotions and interrelationships

The antecedents of emotions were studied separately from each other by multiple-choice options. From the literature in Chapter 6, it is known that these antecedents can be interrelated and have a more collective effect. For example, trust can influence the awareness needed and vice versa. For this research, we did not study the dependencies of the antecedents of emotions. The goal remained exploratory by evaluating the methods of this research to analyze emotions. And secondly, to explore what concerns could be linked to these emotions. However, we should consider these interrelationships for future research, which would make the model in Figure 6.1 more complex. The research methods to test these interrelationships will need to be investigated.

Global research

Respondents of the questionnaire were based in the Netherlands and could originate from and not from Europe. The scope of this research was not to distinguish between different regions. However, we should address that differences in consumer perception could differ per region. To globally implement GMM dairy-based products, it could be essential to look further into the international differences in culture, pressure groups, and interests. As Roeser (2018) argues, emotions are crucial to analyze moral concerns, and demographic variables can influence these emotions. The need for these dairy-based products could differ per global region, which could impact the perception towards GMMs. For example, in areas where food sources are limited, people will be more open to alternatives. For implementing these risky technologies, it is essential to look into these differences because their emotions can be much stronger when it hits society instead of the economy. The emotions point to specific concerns that are most important in these particular regions.

9.5 FUTURE DISCUSSIONS ON STRATEGIES FOR DANONE NUTRICIA RESEARCH

All Danone Nutricia Research experts agree that GMMs is a territory where the company needs to improve in and be sensitive with its internal and external communication. Technical expert 3 stated that "If we do not play in this field, others will do so." At the same time, the social sciences experts argue that the possible enemies of GMMs are not the consumers because they buy them, which is the mistake many people make. Instead, the focus should be on those who protest against your products, which are keen on non-GMO products. It means that public opinion matters, but not so much in itself, but more like how other people perceive public opinions. Danone and other dairy-based companies should extend the research on emotions to study these interactions and the influence of pressure groups. For many years, Danone is very focused on naturality as a dairy-based company. Therefore, most Danone-related experts do not see the early introduction of GMMs for all kinds of products. These experts believe that Danone should not be the frontrunner because dairy-based companies have the most vulnerable consumers with babies and patients. The Danone technical experts are afraid to get the consumers against them, which could be detrimental to the business and lots of resources. The Danone experts also believe that it matters where to introduce GMM products. For example, North America, Latin America, and Israel are much more open than Europe. In the short term, Danone technical experts would like to focus on the contained use of GMMs to produce value-added ingredients.

To conclude, two key topics will be decisive for future successful GMM implementation according to the Danone experts. They would like to implement ethically by looking at its benefits and safety, and the second item is that they must maintain the company image. The company could get a bad reputation because of a too early move, and future discussions arise. Hence, Danone experts stress that they should not run around at each conference talking about GMOs. However, being transparent in publications and clinical studies and highlighting benefits is something they can do. As discussed before, many people are not so convinced by the technical information but more by other people’s values.

10 | CONCLUSION

The dairy-based industry is turning towards responsible, sustainable, and innovative use of genetically modified micro-organisms (GMMs). Genetic engineering has matured rapidly in the past decades, and consumer acceptance is rising. The technology has brought us revolutionary innovations, such as washing detergents, modern insulin for diabetics, and even COVID-19 vaccines. However, early scandals linked to notably GMO plants or animals (e.g., Monsanto) have resulted in a strong anti-GMO lobby and very restrictive regulations in the EU. The EU regulations provide significant loopholes and have not been updated to reflect recent technological progress, and they fail to protect consumer transparency while preventing innovation. As a result, innovation occurs primarily outside the EU's control, and consumers are not aware of the many GMO(-derived) products they already consume. From the latest reports, it seems that the public perception of GMOs is rapidly improving, and NGOs are slowly changing their standpoints under the impact of rapid technological progress. In this research, we specifically studied the perception towards GMMs in the dairy-based industry:

"What are the public emotions and underlying ethical concerns towards genetically modified micro-organisms (GMMs) in dairy-based industry and how to evaluate them?"

The following three paragraphs summarize the findings to the (sub) research questions that helped answer the main research question.

What are the ethical concerns on GMM in comparison to genetically modified animals (GMAs) and genetically modified plants (GMPs)?

The findings of this research conclude that it is a moral question case-by-case, which implies that it is essential to look at specific products, targeted consumers, and their feelings that belong to them. It is also about trust and faith in the company and its industry. For this research, we, therefore, studied the ethical concerns to specific products (Section 7.8.2) to answer (sub) research question two. Hence, the exact type of organism would matter for product acceptance, but it is more than that. Therefore, the literature on GMAs and GMPs could indicate the ethical concerns towards GMMs but should be explicitly studied per product.

What are the public perceptions and emotions towards GMMs?

Different product-specific scenarios were developed on what the future might look like and the role of the specific GMM dairy-based products. These scenarios could help to broaden people's reflections particular to these cases. The theoretical framework of Roeser (2018) helped us understand the most strongly felt

emotions in these scenarios that point to essential ethical concerns. The opinions do not seem to be completely polarized. People seem to have positive and negative emotions towards the technology, where hope and interest overrule fear. The emotions link to awareness, trustworthiness, and autonomy to be essential for product acceptance. For GMMs, as opposed to GMAs and GMPs, it seems that naturalness is not the most critical. People are interested in providing solutions for patients and others that require special medical food. The positive emotions were felt stronger, and the negative ones were felt weaker towards these special types of products (version 1 and version 2 - Q20 Section A.2) instead of the general product, yogurt. The public would accept the technology more when it can bring something to society by adding value to a product or creating a valuable product that does not exist in nature. In this study, the numbers of these extremely negative perceptions towards GMMs were found to be low. It is essential how much pressure they can perform on biotech and what the impact would be.

How do we evaluate the ethical concerns, which include perceptions and emotions?

The results and the research methods were evaluated. The semi-structured interviews and online questionnaires helped us to empirically use Roesers' theoretical framework (2018). However, some discussion points with regards to the sample arose, and a more interactive research method is required to increase reliability. For example, focus groups could help to learn more about emotions and reactions to others, and a lower educated sample could give different results.

The negative emotions, such as the fear that experts have while working on this technology, can help them develop the technology in an ethically responsible way. It helps to build a strategy on products to be implemented first, such as the choice for specific global regions, a contained environment, and no GMO material in the end product. Both laypeople and experts are not ready to find living cultures in the final product. For now, dairy-based companies must focus on producing GMM products for specific reasons that are beneficial to society. With the help of these products, trust can be created by clarifying the potential of the technique. The results show that food companies need to improve their trustworthiness, for which universities and research institutes can play a significant role. At the same time, they must prepare for the fuss that environmental NGOs and other pressure groups could make. Furthermore, companies must collaborate to find and express the key driver to success, such as sustainability goals. And, when product implementation rises, consumers strongly value having the autonomy to choose between different products during the transition towards more GMM products. The awareness will arise once more products become implemented, and the impact of more nuanced and personalized information can have a substantial emotional impact on many people. By being aware of what emotions (positive and negative) play a role, dairy-based companies could contribute to a more compassionate attitude. Hence, emotions help to understand the moral impact and motivation better than from pure scientific information.

11 RECOMMENDATIONS

This chapter provides recommendations for future research on the public's emotions and underlying ethical concerns towards GMMs in the dairy-based industry. It also contains suggestions for dairy-based companies to implement strategies and work more responsibly on genetic engineering in the future. The recommendations are built on the limitations of this research summarized in the first section below.

11.1 LIMITATIONS

There are several limitations of this research. In this paragraph, we specifically consider the sample under study and the research methods. The expert interview sample was limited to 9 individual sessions because of time constraints. More respondents would have led to a more reliable result. Other than that, a higher number of respondents would increase the variability of the sample providing new insights. The semi-structured interviews supplemented the literature study with suitable material to design the questionnaire. However, no interaction between people has been studied because of the individual setting between the interviewee and the researcher. The questionnaire sample was limited to Danone employees and students from the Delft University of Technology based in the Netherlands. No interaction between people was observed since the questionnaire was people responded online. Another limitation of the questionnaire approach was that we analyzed the perception towards three specific product scenarios. Therefore, the results are limited to these particular products, and other products should be studied on a case-by-case basis. Another limitation is that this research only empirically explores the moral considerations of others. Further research is needed to look at the specific concerns more deeply to determine why people feel the emotion linked to them. The following recommendations are given to work on these limitations.

Positive and negative emotions
In the theoretical framework in Chapter 6, we have introduced positive and negative emotions. The valencing of emotions is an assumption we have made, and upon further reflection, it occurred that this valencing shows limiting grounding in literature. This choice would need reconsideration since this research tries to avoid relegating emotions to the irrational. Putting a label on the emotions from the beginning would be another way to think rationally, which could bring up the discussion. The choice of positive and negative emotions will vary based on who you ask, and even the definition of emotion can vary based on who answers the question. The description of emotion, discerning between the two valences, is an

intuitive process. It seems that we "just know" which emotions are positive and which are negative. The results, in the end, seem to be much more mixed. It is not only positive and negative thinking; it is messier.

Case-by-case analysis

As concluded from this research, the emotions and ethical concerns depend on the type of application of genetic engineering. The type of organism, type of product, and targeted consumer can influence consumer perception. A case-by-case analysis is needed to explore the emotions and concerns to other GMM products than investigated within this research.

Questionnaire method

The questionnaire gave valuable insights on the difference in opinion towards genetic engineering in general and towards different dairy-based products. The consumer perception towards the general dairy-based product was studied by multiple-choice questions per emotion, with eight possible antecedents of emotions as the answer. The reliability of these results on Q17 and Q18 was low and must be increased by higher sample size. On the other hand, a more exploratory approach could be used by asking open questions on emotions or using more interactive methods, as described in the following subsection.

Focus groups

A more interactive research method could be used to obtain results on emotions and how others influence them, such as focus groups. The questionnaire could be used as a prior investigation to select people with opposing perceptions to participate in these focus groups.

Type of product

In the short term, experts only see the implementation of GMM products without any foreign GMO material in the final product. In addition, a contained environment is preferred over deliberate release. Therefore, future research on emotions needs to focus primarily on the acceptance of these kinds of products before exploring others. Furthermore, the products' emphasis should be on the groups for which the emotions are triggered the most, when the product does something to society as a whole, such as creating more jobs, making a process more sustainable, or helping patients. For these sorts of products, people would like to get more aware. At the same time, people need to have the freedom to choose between different products. This has a positive influence on trustworthiness and autonomy, which was found to be essential for product acceptance.

Trust building

To built trust, more awareness must be created by information provision and openness to critical questions. The framing (precise fermentation, GMMs, or GEMs,

etc.) and level of information are essential for this and could be further investigated. For further research on this topic, collaborations between universities and research institutes would help to increase the trustworthiness of the results.

Other regions

In some countries, laypeople and experts are much more concerned or afraid of learning about genetic engineering. It has been found that this would primarily occur when the scope is outside the pharmaceutical application of food. US-based companies like to emphasize the disruptive potential of these GMO technologies, while Europe is more silent. Also, countries such as Singapore or China are much more open. The experts of this study hypothesize that these people are more curious because they are constantly striving for the best solution and do not mind where it is coming from if it is safe. From prior research, Europe was found to be more concerned about the environment. Europeans have this very nostalgic idea of how our food should be produced. In countries such as Japan, this is different where they use the technology and food production in a very another way, which is more high-tech based. Also, the legislation on GMMs can differ per region. Canada, for example, looks more product-oriented instead of process-oriented. It does not matter if it is produced by genetic engineering. It goes more about the risks of the final product. Because of these global differences, further research into these perceptions and regulations is needed to develop a responsible introduction of novel GMM products. (The data in this subsection is from semi-structured interviews.)

Company image

The experts hypothesize that Danone is trustworthy when referring to infant food. However, it was found that the respondents would not trust the food market working with GMMs to deliver beneficial products. More research into the company image of Danone specifically and GMMs is needed.

Pressure groups and environmental NGOs

Most experts are more scared of the fuss that environmental NGOs and bigger pressure groups can make instead of the public-at-large. More research into the opinions of these groups of people that are extremely against genetic engineering is needed. In this way, food companies can prepare for future controversies without looking at the consumer per se. An overview of the most prominent opponents towards genetic engineering, and any specifically against GMMs, can be developed. With this overview, it can be concluded who is influential and why they are against GMMs. To research the enemies, trustworthy companies like Danone need to use independent institutions like universities to study the criteria for the organizations. And not as one company but as an association of food companies to discuss support to avoid the backlash. However, the policy expert experienced that non-profit organizations and NGOs working on food and health-related products do not seem to see the relevance of a discussion on future GMM products. The organizations ask how relevant it is and if there is a product already on the

market or very close to coming on the market. They also ask if the legislation affects those kinds of GMM products. If those conditions are not met, then it is hard to have those conversations.

Danone departments

The Danone experts hypothesized that differences in perception towards genetic engineering occur between departments such as legal and secretary. For this study, the sample size per department was too small to draw any significant conclusions. The questionnaire can be distributed among more people per department and other departments per global region for further research. The Danone experts hope that this research will help internally to find a way to work with GMMs and their opportunities and be ethical at the same time.

Enzyme suppliers or other biotech-related companies

Big food companies could collaborate with smaller companies that work on recombinant enzymes or other biotech-related technologies. It would help to challenge the internal experts by external experts on their territory. The opinion of these smaller companies could offer insights for an approach on the implementation and marketing of GMMs.

Trends

By linking GMM products to a particular trend, the products follow the quickest, easy, and emotionally addressed benefits. The movement does not have to do anything with genetic engineering specifically. Think, for example, of 'freedom to vote' where the right propaganda was used to promote cigarettes which are bad for human health. Women were passively supporting this idea of freedom and voting rights by going to smoke. For GMMs specifically, the technology could be linked to sustainability. In the recently published climate rapport from the IPCC (Intergovernmental Panel on Climate Change), the United Nations (UN) clearly explains what is needed to help the world and what will happen if we do not change to more sustainable production processes. Companies can use the consequences of climate impact to promote the use of GMMs.

Education

In the long run, education starting from a young age and specifically targeted at tackling common misconceptions might immunize the population against unsubstantiated anti-GMO messages. Other concerns can be addressed and discussed in the broader context of agricultural practices and the place of science and technology in society. However, for now, the best way to turn the tide and generate a more positive public response to GMOs is to play into people's intuitions. It is essential to emphasize the benefits of current and future genetic engineering applications.

Experts and laypeople

In addition to laypeople, the opinion of experts should also be studied. Experts may also differ in opinion. The experts' negative emotions, such as fear, could link to concerns that must be considered to develop the technology in an ethically responsible way. It could be interesting to study experts' and lay people's views by mixed focus groups.

11.1.1 Ethical discussion

Because of time constraints, this research only empirically studies the ethical considerations of others. Further research is needed to ethically discuss the results from the researcher's point of view.

11.2 THEORETICAL CONTRIBUTION

Roeser's (2018) theoretical framework helped study the results using emotions rather than only instrumentally using the findings (e.g., CBA). Without using the theoretical framework of Roeser (2018), we would miss several recommendations listed above. When such future research on public perception is neglected, a controversy could arise, such as described in the preface (Chapter 1). With the help of product-specific scenarios, we put people in a situation with specific needs. For Danone Nutricia Research, interestingly, this research shows that there is more openness to GMMs than before to GMOs. The product scenarios bring up emotions, which is different from just asking people straight away if they think genetic engineering is favorable or not. We broadened how the public's perception can be understood, where focus groups can also help understand the response to each other, reflecting real life.

We have experienced that experts express emotions such as fear without asking too much about emotions. Hence, experts use language that is emotional apart from the expected technical language. According to Roeser's theoretical framework, it seems logical that all people express emotions while this can be different for the public. Therefore, the perception of both laypeople and experts is essential for the future development of this technology. The question arises whether we should think about experts and laypeople in different ways or not.

In previous debates on GMAs and GMPs, naturalness was strongly valued and reviewed by several research groups (e.g., Frewer et al.). However, this research shows that people strongly value autonomy, trustworthiness, and awareness. Lastly, the opinions do not seem to be completely polarized. The public appears to mix positive and negative emotions, which makes them doubtful about the technology.

12 | REFLECTION

With this thesis project I complete my double degree in MSc Life Science and Technology and MSc Management of Technology at the Delft University of Technology. My first thesis project for MSc Life Science and Technology focused on the more technical side of genetic engineering. I worked mainly in the lab to characterize an unknown byproduct from an enzymatic reaction. During that time, I developed several skills focusing on biotechnological analytical techniques and problem-solving. This specific document continues on genetic engineering but in more social sciences and ethical ways. I had the chance, as biotech expert, to understand laypeople's opinions towards genetic engineering. I have worked with great pleasure on these topics, and it was easy to continue with the second thesis because of their interrelationship. I performed both tasks within Danone Nutricia Research because they allowed fulfilling my double degree within their company. In one year, I had the chance to contact many people despite the COVID-19 situation. The Danone Nutricia Research employees helped me to find the right people for this research. This project felt very different from the other master's thesis because I did not spend time anymore in the lab. I also needed to use different research methods, which made me improve my soft skills.

It was the first time that I executed interviews myself. By making them semi-structured, I had a helpful guideline to follow, not to forget essential discussion points. At the same time, it gave me the freedom to bring up new topics of discussion. The interviews were an exciting experience because of the many experts who gave me valuable new insights into this technology and research. The interviews with social sciences experts helped me know more about this field since my background is more technical. I found out that MSc Management of Technology was the perfect choice next to my other MSc degree to expand my network within biotechnology, to develop soft skills, and to work in an ethically responsible way. From the start of Management of Technology, I already knew that I would like to study this research topic (perception towards genetic engineering). Professors such as Roeser were an inspiration for me during the first year of MSc Management of Technology. Since I was interested in genetic engineering and ethics, I mainly focused on the study material from the course 'Social Sciences & Scientific Values.' The theoretical material helped to study the results and explain the theoretical framework in Chapter 6. Other courses such as 'Research Methods' given by Mark de Reuver helped me perform the interviews and questionnaire. However, the more practical application of these theories was missing during these courses. Especially for statistical analysis, which I do think is essential for many students' careers. I would have liked to design and analyze a questionnaire on a topic of interest with a group of students. Hence, the theory would have been easier to understand and implement in my thesis but also in future jobs/research.

During this research, I had the chance to talk to fascinating people in the biotech field. It helped me to understand what I would like to do after my academic career. The interviews also helped me broaden my knowledge and gave me valuable new insights into the latest applications in the dairy-based industry. Because of the COVID-19 situation, it was sometimes difficult to get motivated in the beginning. I especially experienced this feeling in the first month since the second thesis project came right after the other. In contradiction with the previous thesis project, I needed to work more individually and at home. However, the interviews and other meetings with supervisors helped me stay focused and enjoy it until the end.

BIBLIOGRAPHY

Aguilera, J., Gomes, A. R., and Olaru, I. (2013). Principles for the risk assessment of genetically modified microorganisms and their food products in the European Union. *International Journal of Food Microbiology*.

Angel, J. and Alberto, H. (2012). Genetic Engineering and Biotechnology of Growth Hormones. In *Genetic Engineering - Basics, New Applications and Responsibilities*.

Asveld, L. and Roeser, S. (2009). *The ethics of technological risk*. Earthscan.

Bauer-Panskus, A., Miyazaki, J., Kawall, K., and Then, C. (2020). Risk assessment of genetically engineered plants that can persist and propagate in the environment. *Environmental Sciences Europe*.

Beer, T. L. d. (2015). *Stakeholder Involvement In the Development of Genetically Modified Food Labelling Policy in South Africa*. PhD thesis.

Belderok, A. (2021). The protein revolution. Technical report.

Belderok, A., Vries, A. G. d., and Spek, L. v. d. (2021). GENETICALLY MODIFIED ORGANISMS IN FOOD AND BEVERAGES. Technical report, Roland Berger, Amsterdam.

Benjamin C. Heddy, Robert W. Danielson, G. M. S. . J. G. (2017). Modifying Knowledge, Emotions, and Attitudes Regarding Genetically Modified Foods. *The Journal of Experimental Education*, 85:3:513–533.

Blancke, S. (2015). Why People Oppose GMOs Even Though Sciecne Says They Are Safe.

Boenink, M., Swierstra, T., and Stemerding, D. (2010). Anticipating the interaction between technology and morality: A scenario study of experimenting with humans in bionanotechnology. *Studies in Ethics, Law, and Technology*.

Briesemeister, B. B., Kuchinke, L., and Jacobs, A. M. (2012). Emotional valence: A bipolar continuum or two independent dimensions? *SAGE Open*.

Carnevale, P. J. and Isen, A. M. (1986). The influence of positive affect and visual access on the discovery of integrative solutions in bilateral negotiation. *Organizational Behavior and Human Decision Processes*.

CBS (2018). Education - Figures - Society.

Cgm, C. (2006). Comments on the European Food Safety Authority ' Guidance on the Post-Market Environmental Monitoring of genetically modified plants '. pages 1–3.

Coombs, C. (2017). Coherence and transparency: Some advice for qualitative researchers. *Production*.

Correljé, A., Cuppen, E., Dignum, M., Pesch, U., and Taebi, B. (2015). Responsible innovation in energy projects: Values in the design of technologies, institutions and stakeholder interactions. In *Responsible Innovation 2: Concepts, Approaches, and Applications*.

Cross, F. B. (1998). Facts and values in risk assessment. *Reliability Engineering and System Safety*.

Damasio, A. (1994). *Descartes' error: Emotion, rationality and the human brain*.

Danone (2021). Danone Nutricia Research.

Deckers, M., Deforce, D., Fraiture, M. A., and Roosens, N. H. (2020). Genetically modified micro-organisms for industrial food enzyme production: An overview. *Foods*, 9(3).

Dunn, J. R. and Schweitzer, M. E. (2005). Feeling and believing: The influence of emotion on trust. *Journal of Personality and Social Psychology*.

Dürnberger, C. (2019). Normative Concepts of Nature in the GMO Protest. A Qualitative Content Analysis of Position Papers Criticizing Green Genetic Engineering in Germany. *Food Ethics*.

EFSA (2011a). Guidance for risk assessment of food and feed from genetically modified plants. *EFSA Journal*, 9(5):2150.

EFSA (2011b). Guidance on the risk assessment of genetically modified microorganisms and their products intended for food and feed use. *EFSA Journal*, 9(6):1–54.

EFSA (2013). Guidance on the environmental risk assessment of genetically modified animals. *EFSA Journal*, 11(5):1–190.

Ellahi, B. (1994). Genetic Engineering for Food Production - What Is It All About? *British Food Journal*.

Ellahi, B. (1996). Genetic modification for the production of food: The food industry's response. *British Food Journal*.

European Union (2021). Food safety.

Fentiman, L. C. (2010). Marketing Mothers' Milk: The Commodification of Breastfeeding and the New Markets for Breast Milk and Infant Formula. *Nevada Law Journal*, 10:29:1–53.

Ferguson, J. L., Ellen, P. S., and Bearden, W. O. (2014). Procedural and Distributive Fairness: Determinants of Overall Price Fairness. *Journal of Business Ethics*.

Forgas, J. P. (1995). Mood and judgment: The affect infusion model (AIM). *Psychological Bulletin*.

Frewer, L. J., Coles, D., Houdebine, L. M., and Kleter, G. A. (2014). Attitudes towards genetically modified animals in food production. *British Food Journal*.

Frewer, L. J., Howard, C., and Shepherd, R. (1995). Genetic engineering and food: What determines consumer acceptance? *British Food Journal*.

Frewer, L. J., Howard, C., and Shepherd, R. (1996). Effective communication about genetic engineering and food. *British Food Journal*.

Frewer, L. J. and Shepherd, R. (1995). Ethical concerns and risk perceptions associated with different applications of genetic engineering: Interrelationships with the perceived need for regulation of the technology. *Agriculture and Human Values*.

Frewer, L. J., van der Lans, I. A., Fischer, A. R., Reinders, M. J., Menozzi, D., Zhang, X., van den Berg, I., and Zimmermann, K. L. (2013). Public perceptions of agri-food applications of genetic modification - A systematic review and meta-analysis. *Trends in Food Science and Technology*.

Gaivoronskaia, G. and Solem, K. E. (2001). Managing risks in biotechnology: Can we learn from nuclear power?

Garcia-Yi, J., Lapikanonth, T., Vionita, H., Vu, H., Yang, S., Zhong, Y., Li, Y., Nagelschneider, V., Schlindwein, B., and Wesseler, J. (2014). What are the socio-economic impacts of genetically modified crops worldwide? A systematic map protocol. *Environmental Evidence*, 3(1):24.

Gideon, L. (2012). The art of question phrasing. In *Handbook of Survey Methodology for the Social Sciences*.

Giezen, A. V. V. (2018). Effects of cumulative social impacts on emotions regarding ultra-deep geothermal energy projects.

Gregg, B. (2017). Human genetic engineering: Biotic justice in the anthropocene? In *Encyclopedia of the Anthropocene*.

Haidt, J. (2004). Elevation and the positive psychology of morality. In *Flourishing: Positive psychology and the life well-lived.*

Hanlon, P. and Sewalt, V. (2021). GEMs: genetically engineered microorganisms and the regulatory oversight of their uses in modern food production.

Hanna, P., Vanclay, F., Langdon, E. J., and Arts, J. (2016). Conceptualizing social protest and the significance of protest actions to large projects.

Hunt, S. and Frewer, L. J. (2001). Trust in sources of information about genetically modified food risks in the UK. *British Food Journal*.

Jones, L. (1996). Food biotechnology: Current developments and the need for awareness. *Nutrition & Food Science*.

Jurkiewicz, A., Zagórski, J., Bujak, F., Lachowski, S., and Florek-Łuszczki, M. (2014). Emotional attitudes of young people completing secondary schools towards genetic modification of organisms (GMO) and genetically modified foods (GMF). *Annals of Agricultural and Environmental Medicine*.

Kahneman, D. (2011). Thinking fast, thinking slow.

Knox, B. (2000). Consumer perception and understanding of risk from food. *British Medical Bulletin*.

Kroll, J. and Egan, E. (2004). Psychiatry, moral worry, and the moral emotions.

Kuckartz, U. (2009). Qualitative Inhaltsanalyse. Methoden, Praxis, Computerunterstützung. *Qualitative Inhaltsanalyse. Methoden, Praxis, Computerunterstützung*.

Lee, W. S. and Selart, M. (2012). The impact of emotions on trust decisions. In *Handbook on Psychology of Decision-Making: New Research*.

Leucht, M., Kölbel, T., Laborgne, P., and Khomenko, N. (2010). The Role of Societal Acceptance in Renewable Energy Innovations´BreakthroughInnovations´Breakthrough in the Case of Deep Geothermal Technology. *Proceedings World Geothermal Congress*.

Mayring, P. and Fenzl, T. (2014). Qualitative Inhaltsanalyse. In *Handbuch Methoden der empirischen Sozialforschung*.

Miles, S., Ueland, , and Frewer, L. J. (2005). Public attitudes towards genetically-modified food. *British Food Journal*.

Mishra, S., Sachan, A., and Sachan, S. G. (2013). Production of natural value-added compounds: An insight into the eugenol biotransformation pathway. *Journal of Industrial Microbiology and Biotechnology*.

Mora, C., Menozzi, D., Kleter, G., Aramyan, L. H., Valeeva, N. I., Zimmermann, K. L., and Reddy, G. P. (2012). Factors affecting the adoption of genetically modified animals in the food and pharmaceutical chains. *Bio-based and Applied Economics*.

Myhr, A. I. (2010). A Precautionary Approach to Genetically Modified Organisms: Challenges and Implications for Policy and Science. *Journal of Agricultural and Environmental Ethics*.

Myhr, A. I. and Traavik, T. (2007). GE Applications and GMO Release: The Ethical Challenges. In *Biosafety First*, chapter 7. Tapir Academic Publishers.

Ormandy, E. H., Dale, J., and Griffin, G. (2011). Genetic engineering of animals: Ethical issues, including welfare concerns. *Canadian Veterinary Journal*.

Pyne, M., Sukhija, K., and Chou, C. P. (2019). Genetic engineering. In *Comprehensive Biotechnology*.

Rajan, S. R. and Letourneau, D. K. (2012). What risk assessments of genetically modified organisms can learn from institutional analyses of public health risks. *Journal of Biomedicine and Biotechnology*.

Renn, O. (1998). The role of risk perception for risk management. *Reliability Engineering and System Safety*.

Riddell, W. C. and Song, X. (2017). The Role of Education in Technology Use and Adoption: Evidence from the Canadian Workplace and Employee Survey. *ILR Review*, 70(5):1219–1253.

Roeser, S. (2018). *Risk, technology, and moral emotions*.

Roeser, S. and Pesch, U. (2016). An Emotional Deliberation Approach to Risk. *Science Technology and Human Values*.

Ryland, D. (2001). Regulating genetically modified organisms in the interests of whom? *Managerial Law*.

Saba, A., Moles, A., and Frewer, L. J. (1998). Public concerns about general and specific applications of genetic engineering: A comparative study between the UK and Italy. *Nutrition & Food Science*.

Savadori, L., Savio, S., Nicotra, E., Rumiati, R., Finucane, M., and Slovic, P. (2004). Expert and public perception of risk from biotechnology. *Risk Analysis*.

Scully, J. (2003). Genetic engineering and perceived levels of risk. *British Food Journal*.

Siipi, H. and Uusitalo, S. (2011). Consumer Autonomy and Availability of Genetically Modified Food. *Journal of Agricultural and Environmental Ethics*.

Skovgaard, N. (2005). Safety of Genetically Engineered Foods. Approaches to Assessing Unintended Health Effects. *International Journal of Food Microbiology*.

Slovic, P. (2016). *The perception of risk*.

Šorgo, A., Jaušovec, N., Jaušovec, K., and Puhek, M. (2012). The influence of intelligence and emotions on the acceptability of genetically modified organisms. *Electronic Journal of Biotechnology*.

Stemke, D. J. (2004). Genetically Modified Microorganisms. In *The GMO Handbook*.

Straughan, R. (1990). Genetic Manipulation for Food Production: Social and Ethical Issues for Consumers. *British Food Journal*.

Taebi, B. (2017). Bridging the Gap between Social Acceptance and Ethical Acceptability. *Risk Analysis*.

Tripathi, A. D., Mishra, R., Maurya, K. K., Singh, R. B., and Wilson, D. W. (2018). Estimates for world population and global food availability for global health. In *The Role of Functional Food Security in Global Health*.

Tversky, A. and Kahneman, D. (1974). Judgment under Uncertainty - Heuristics and Biases Tversky Kahneman 1974. *Science*.

Tyagi, S., Kesiraju, K., Saakre, M., Rathinam, M., Raman, V., Pattanayak, D., and Sreevathsa, R. (2020). Genome editing for resistance to insect pests: An emerging tool for crop improvement.

Van Den Bos, K., Vermunt, R., and Wilke, H. A. (1997). Procedural and Distributive Justice: What is Fair Depends More on What Comes First Than on What Comes Next. *Journal of Personality and Social Psychology*.

Verdurme, A. and Viaene, J. (2003). Exploring and modelling consumer attitudes towards genetically modified food. *Qualitative Market Research: An International Journal*.

Widyarini, I. (2018). The role of negative moral emotions (anger and disgust) in ethical decision making.

Wood, M. O. and Thistlethwaite, J. (2018). Social License to Operate (SLO). In *Handbook of Engaged Sustainability*.

Xu, W. and Zammit, K. (2020). Applying Thematic Analysis to Education: A Hybrid Approach to Interpreting Data in Practitioner Research. *International Journal of Qualitative Methods*.

Zhang, Y., Jing, L., Bai, Q., Shao, W., Feng, Y., Yin, S., and Zhang, M. (2018). Application of an integrated framework to examine Chinese consumers' purchase intention toward genetically modified food. *Food Quality and Preference*.

A APPENDIX

A.1 QUESTIONS SEMI-STRUCTURED VIDEO-RECORDED INTERVIEWS

1 - To understand their knowledge on GMOs in general
a) What is your experience with GMOs?
b) What is your definition of GMMs?
c) What do you understand as the key differences between GMAs, GMPs, and GMMs?
d) What do you see as the advantages and disadvantages of GMMs?

2 - To understand the expert's knowledge on risks and GMMs
a) What do you think are the risks involved with GMMs?
b) Do you know how the risks of GMMs are currently assessed?
c) How do you think the public perceives the risks of GMMs? (let the experts speculate if the public is aware of GMMs and their risks) And how does this differ from GMAs and GMPs?

3 - To understand the ethical concerns towards GMMs
a) What kind of ethical concerns do you think are related to GMMs (refer to the literature, type of consumer, type of organisms, type of product)?
b) Do you think that these ethical concerns are relevant to consider?
c) How should the ethical concerns on GMMs differ from GMAs and GMPs? Are there overlapping concerns between these and how should they be addressed?
d) How are the ethical issues being addressed/handled (by companies, regulators, policy makers, other bodies)?

4 - To understand the public emotions towards GMMs
a) What emotions related to GMMs do you think are most salient?
b) How should the emotions be considered for technology acceptance?
c) You might have noticed that the focus was put on the emotions of the public. Do you have an idea on how to integrate these in e.g. the risk assessment of GMMs.

5 - To understand the experts' specific emotions towards GMMs
(a) What is your perception towards and how do you feel about GMM technology and its products?
(b) Would you object to a product and why? Or why not? What are the conditions you would object under?
(c) If your company would use GMMs, how do you feel about this?
Do you have anything in mind what we would still discuss?

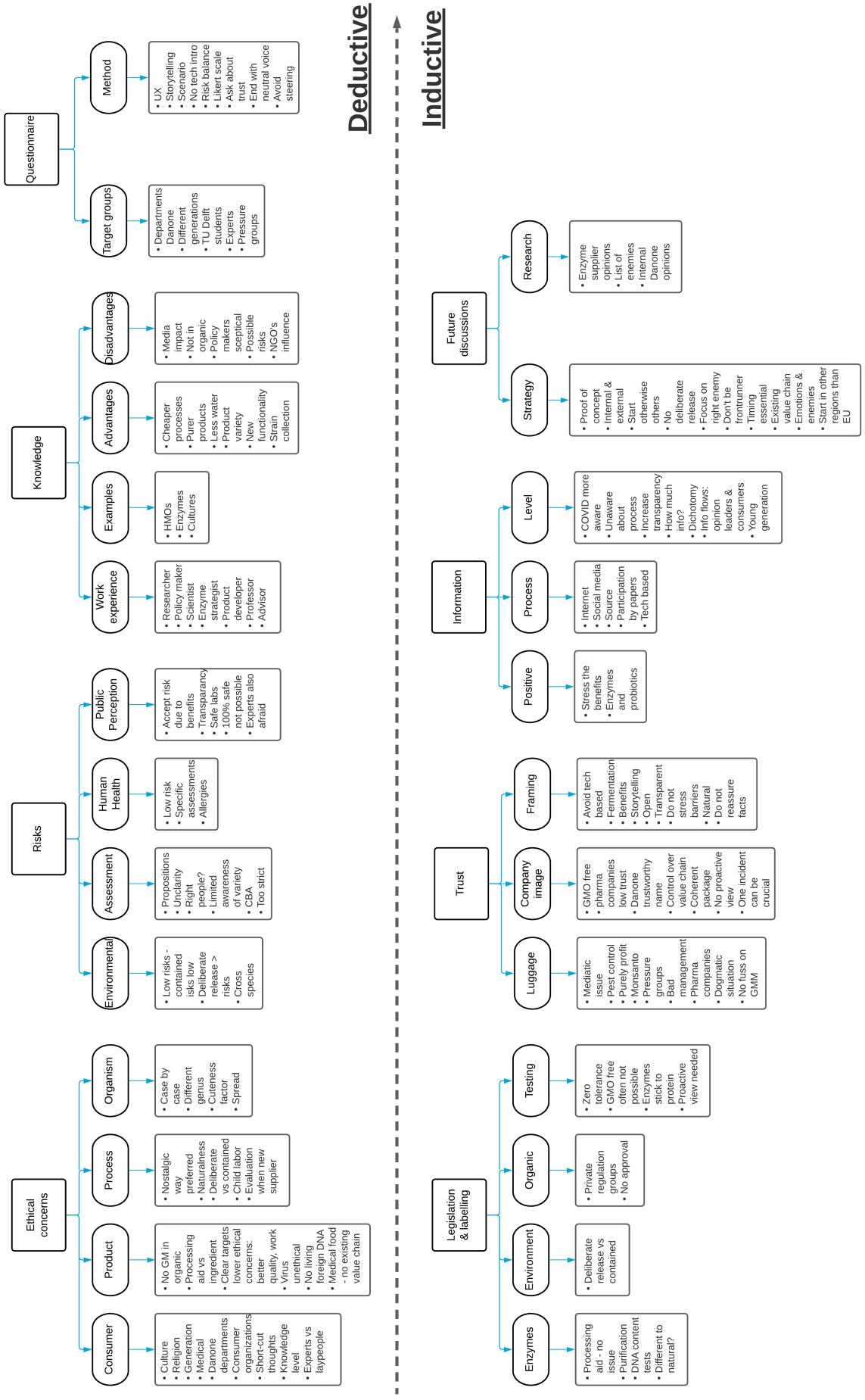


Figure A.1: An overview of the categories, themes, and sub-themes obtained from deductive/inductive thematic analysis.

A.2 QUESTIONNAIRE

The questionnaire consists of four specific parts. In the first section, respondents need to provide some information regarding demographic variables and their understanding of the technology. The two following sections introduce specific scenario descriptions with their related questions to study the emotions. In the last section, questions go about risk perception and future interest. Two versions of the questionnaire have been created by adding different particular product scenarios (Q20). These questionnaires were distributed among Danone employees and TU Delft students after consent was given.

Section 1: personal data and understanding

1. My gender is:
   Woman (1) Man (2) Non-binary (3) Prefer not to say (4)
2. My country of origin is (I was raised in):
3. My year of birth is:
4. My highest level of education is:
   Primary school (1) Lower vocational education (2) Lower secondary education (MAVO, VMBO) (3) Senior secondary vocational education (MBO) (4) High school (HAVO, VWO) (5) Higher vocational education (HBO) (6) Academic education (WO/University) (7) Other (8)
5. If TU DELFT student - I am a student of the faculty:
   Aerospace Engineering (1) Applied Sciences (2) Architecture and the Built Environment (3) Civil Engineering and Geosciences (4) Electrical Engineering, Mathematics and Computer Science (5) Industrial Design Engineering (6) Mechanical, Maritime and Materials Engineering (7) Technology, Policy and Management (8) QuTech (9) Other (10)

   If DANONE EMPLOYEE - I am working at:
   Assistant (1) Finance (2) Cycles Procurement (3) General Secretary (4) Human Resources (5) Legal (6) Marketing (7) Marketing & Health Affairs (8) Quality & Food Safety (9) Research & Innovation (10) Sales (11) Regulatory (12) Other (13)
6. Do you take any food for medical purposes? For example, formulated dietary products.
   Yes (1) No (2) Prefer not to say (3)
7. Do you have any food-related allergies?
   Yes (1) No (2) Prefer not to say (3)
8. Are you familiar with genetic engineering?
   Yes (1) No (2)
9. What do you think when you hear about genetic engineering (max. 1 sentence)

10. From which information source have you heard, read or seen anything related to genetic engineering? (multiple answers are possible)
    Events (e.g., conferences) (1) Social media (2) Education (3) Friends (4) Work (5) Other (6)

11. Do you know what micro-organisms are?
    Yes (1) No (2)

12. Read the following statement carefully and answer the question below. "With the help of genetic engineering new compounds can be produced to make existing dairy products healthier and more nutritious." Which source do you trust? (multiple answers are possible)
    Food companies (1) Greenpeace or other environmental NGO's (2) University (3) Research institutes (4) Government (5) Social media (6) Famous people (7)

Section 2: general product scenario

13. Please read the following sentence carefully and think about how it makes you feel! When I say "Genetic Engineering", "Genetic Modification", "Altering of DNA". Think about these concepts for a moment. How do you feel about these concepts? Please indicate how strong you feel the following emotions when you think about the statements above. Select 'does not apply' if you do not experience the emotion.
    Rank the emotions (interest, surprise, fear, anger, joy, disgust, hope, irritation, happiness, powerlessness) on a 6-point Likert-scale: Weak (1) Slightly weak (2) Neutral (3) Slightly strong (4) Strong (5) I do not know (6)

14. Please write down if you feel another emotion (1 word). Otherwise, leave open and continue.

15. I am more comfortable with genetic engineering when applied to... (Please place the items in order of most acceptable to the least acceptable)
    Animals (1) Micro-organisms (2) Plants (3) I do not care (4)

16. The ranking above is based on:
    Possible risks (1) Sustainability (2) Cuteness (3) Closer to humans (4) Other (5)

17. You will now be given instructions regarding the situation we would like you to remember. It is very important to the study that you understand and follow these instructions. Please read carefully! We will give you a short description on what kind of genetic engineering we would like to talk about.
    "Since 1860 food production has become more efficient due to industrialization. It seems that after this revolution there is a new industrial revolution happening with regards to biotechnology. With the help of genetic engineering, the DNA of animals, plants and micro-organisms can be altered to produce a desired product. These products can be kept contained or spread into the environment. Imagine a micro-organism; a small bacterium or fungus that lives in cultures together and can multiply and share DNA very fast. The potential of these genetically engineered micro-organisms is enormous

within the food industry. They allow the development of products in a more sustainable and efficient way. The micro-organism will be developed in laboratory settings and be kept in a bioreactor for production. The environmental and health risks have been studied and assessed to be very low. The micro-organism will be grown and will produce certain ingredients that will be added in a yoghurt. This yoghurt will not contain any foreign DNA material." The following questions are linked to the scenario above. We provide you with an emotion linked to certain values. Select the answer(s) that best describe(s) your feelings.

I feel the emotion (for each of the emotions interest, joy, hope, surprise, happiness) because...
I do not feel this emotion (1) The process or product is new and exciting (2) The risks are worth the benefits (3) The risks are fair to all (4) I am confident this is well-researched and understood (5) I trust the companies or institutions involved in this (6) People will be given opportunities to choose this or not (7) Other (8)

18. I feel the emotion (for each of the emotions anger, fear, disgust, irritation, powerlessness) because...
I do not feel this emotion (1) The process or product is unnatural (2) The risks are not worth the benefits (3) The risks are not fair to some (4) There are many unknowns (5) I do not think this process can be trusted to certain companies or institutions (6) People may not have a choice about this (7) Other (8)

19. Please write down if you feel another emotion (1 word). Otherwise, leave open and continue.

Section 3: special product scenario

20. **Version 1:** Now imagine that you are a young mother or father and you are going to buy infant formula. Before buying, you do some research online. You find that before infant formula existed, breast milk was the only source of nutrition for babies. For many years, companies have been investing in the right infant formula to enhance the babies' health. The supplements that are beneficial for the health of a baby can only be produced by genetically engineered micro-organisms in a contained environment. Because harvesting the milk of young mothers is unethical. Since the global demand for infant formula is high, imagine that dairy-based companies started to produce these supplements by genetically engineered micro-organisms. The final product does not contain any foreign DNA material. Please indicate if the strength of your emotional feelings are stronger, equal or weaker when you compare this situation with the previous one. Select 'does not apply' if you do not experience the emotion. Rank the emotions (interest, surprise, fear, anger, joy, disgust, hope, irritation, happiness, powerlessness) on a 6-point Likert-scale: Weaker (1) Slightly weaker (2) Neutral (3) Slightly stronger (4) Stronger (5) Does not apply (6)

Version 2: Now imagine that you are a patient suffering from a metabolic disorder. This means that you cannot consume particular compounds from nature. You turn yellow, lose weight, show lethargy and sometimes lose consciousness. Now, you have the choice to eat freely with the help of a product which is produced by a genetically modified micro-organism in a contained environment. The final product does not contain any foreign DNA material. Please indicate if the strength of your emotional feelings are stronger, equal or weaker when you compare this situation with the previous one. Select 'does not apply' if you do not experience the emotion.
Rank the emotions (interest, surprise, fear, anger, joy, disgust, hope, irritation, happiness, powerlessness) on a 6-point Likert scale: Weaker (1) Slightly weaker (2) Neutral (3) Slightly stronger (4) Stronger (5) Does not apply (6)

21. Please write down if you feel another emotion (1 word). Otherwise, leave open and continue.

Section 4: understand risk perception and future interest

21. Do you think genetic engineering is safe?
Yes (1) No (2) I do not know (3)

22. Read the following questions and select one of the answers that fits best with your opinion. With respect to genetic engineering of micro-organisms:
Answer the following questions on a 6-point Likert-scale: Very mild (1) Mild (2) Neutral (3) Moderate (4) Severe (5) I do not know (6)
Question 1: "To what extent do you think your body is at risk?" Question 2: "To what extent do you think the environment is at risk?"

23. Read the following statements and select one of the answers that fits best with your opinion. With respect to genetic engineering:
Rank the following statements on a 6-point Likert-scale: Strongly disagree (1) Disagree (2) Neither agree or disagree (3) Agree (4) Strongly agree (5) I do not know (6)
Statement 1: "I believe that the benefits outweigh the risks." Statement 2: "I believe it can make food production processes more sustainable." 3: "I believe that it is necessary to invest in this technology." 4: "I am aware about the different products." 5: "I would only accept the product when a clear extra benefit is given."

24. Read the following question and select one of the answers that fits best with your opinion. With respect to genetic engineering of micro-organisms:
Answer the following question on a 6-point Likert-scale: Very unconcerned (1) Somewhat unconcerned (2) Neutral (3) Somewhat concerned (4) Very concerned (5) I do not know (6)
Question: "How concerned are you about the technique?"

25. Read the following statement and select one of the answers that fits best with your opinion. With respect to genetic engineering of micro-organisms:
Answer the following question on a 6-point Likert-scale: Strongly disagree (1) Disagree (2) Neutral (3) Agree (4) Strongly agree (5) I do not know (6)
Statement: "I would like to know more about the specifics of the technique.

A.3 CODING SCHEMES

Table A.1: The coding scheme of multiple-choice and closed questions for the data analysis of the online-questionnaire. Variables were measured at a nominal level. *Faculty and department were coded 1-N respectively to the questionnaire answers in Section A.2.

Question	Variable	Code: 1	Code: 2	Code: 3	Code: 4	Code: 5
Q1	Gender	Woman	Man	Non-binary	Prefer not to say	
Q2	Origin	from Europe	Not from Europe			
Q3	Age	18-25	26-35	36-45	46-55	56-66
Q6 & Q7	Medical food & allergies	Yes	No	Prefer not to say		
Q8	Familiar	Yes	No			
Q9	Thoughts	+	-	+/-	Neutral	
Q11	Micro-organisms	Yes	No			
Q17	Ranking	Possible risks	Sustainability	Cuteness	Closer to humans	Other
Q21	Safe	Yes	No	I do not know		
Q10 & Q12 & Q17 & Q18	Multiple choice Q	Not-selected	Selected			

Table A.2: The coding scheme of 6-point Likert-scale questions for the data analysis of the online-questionnaire. Variables were measured at the ordinal level. *Education was coded 1-n respectively to the questionnaire answers in Table 8.3.

Question	Variable	1	2	3	4	5	6
Q13	Emotions	Weak	Slightly weak	Neutral	Slightly strong	Strong	Does not apply
Q15	Organisms	Most acceptable	2nd choice	3th choice	Least acceptable		
Q20	Emotions	Weaker	Slightly weaker	Neutral	Slightly stronger	Stronger	Does not apply
Q22	Risk	Very mild	Mild	Neutral	Moderate	Severe	I do not know
Q24	Concern	Very unconcerned	Somewhat unconcerned	Neither unconcerned nor concerned	Somewhat concerned	Very concerned	I do not know
Q23 & Q25	Perception	Strongly disagree	Disagree	Neither agree nor disagree	Strongly agree	Agree	I do not know

A.4 STATEMENTS POSITIVE AND NEGATIVE

- That it is maybe better not to do it, but for sure it has advantages
- Good when done it's done the right way for the right purposes
- How it can deal with genetic diseases, struggles with ethics and it being risky.
- Probably Makes the world more efficient, but the question is if we want that sort of efficiency.
- A double-edged sword that can either be positive or negative
- Probably a good way of feeding the world if it's only used for plants
- The future (with ethical policies in place)
- Needs to be used with care, but can improve humans quality of life
- I think it's advantageous for our society to do it on food, however genetically engineering humans is unethical in my eyes.
- Food that has been altered, could be either good or bad depending on who does it I guess.
- Beneficial but also risky.
- That it is related to solving or being aware and treat medical issues
- Genetic engineering has a high potential, but it requires time to make sure it is safe and make no harm
- Amazing and mindblowing technology, but only to be used for the good humanitary cause.

- I believe genetic engineering, if wisely used, can create great progress
- New opportunities, maybe also a bit risky? Hopefully better for the environment.
- it has made new and exciting discoveries possible in medicine, agriculture, there is also a danger, possibly the consequences are not fully understood, does not have a great reputation esp in food
- I don't like the idea but it's - still- an innovation that we need to welcome to preserve the ecosystem
- Guessing it should be the combination of elements to create food, proper to help individual heath
- manipulation of DNA, advanced science which can help us, but is controversial
- Should be careful but with it but can bring benefits
- Ideal but tasteless products
- Cheaper and easier production of Fruit/Veg but reduction on biodiversity. Possible health implications
- Genetic manipulation which can have a positive influence on e.g. agriculture but is not widely accepted in the wider population (GMOs)
- Complex topic with many areas of application
- It can be very useful but not all the risks are know.
- Since it is an unknown field, I feel both curious to know more and also doubts/distrust
- If it is used wisely, it can have a positive effect on the human society
- Somewhat in between hope and fears
- Efficiency vs transfer of genes to other species and the issues of reuse of genitive engineered seeds harvests - Monsanto

A.5 FREQUENCY TABLES

Table A.3: The distribution of percentages (both versions 1 and 2) of degree of responses to statements on genetic engineering (Q23) and GMMs (Q25) on a 6-point Likert-scale. (Q23 and Q25 - Section A.2)

N=171, values in %	Q23.1	Q23.2	Q23.3	Q23.4	Q23.5	Q25
1 (Strongly Disagree)	2.9	0	0	3.5	0	0
2 (Disagree)	4.7	3.5	3.5	21.1	10.5	2.9
3 (Neither agree or disagree)	21.1	5.8	10.5	26.9	18.7	9.4
4 (Agree)	41.5	50.9	47.4	24.6	38.0	53.2
5 (Strongly agree)	16.4	32.2	35.1	7.6	27.5	34.5
6 (I do not know)	13.5	7.6	3.5	16.4	5.3	0
Total	100	100	100	100	100	100
Mean (Scores 1-6)	4.19	4.04	4.35	4.25	3.61	3.98
Std. Deviation	0.722	1.170	0.842	0.825	1.420	1.049

A.6 LEVENE TESTS

Table A.4: Levene test results to test homogeneity of variance.

	N	Levene statistic	df1	df2	Sig.
Q24	Based on Median and with adjusted df	6.209	1	163.450	.014
Q21	Based on Median and with adjusted df	1.300	3	155.715	.276
Q22.1	Based on Median and with adjusted df	1.541	4	153.957	.193
Q22.2	Based on Median and with adjusted df	.761	4	160.305	.552

A.7 SPEARMAN'S RHO

Table A.5: The Spearman's rho correlation test on familiarity (yes/no) with genetic engineering and the ordinal responses to Q24 about level of concern towards genetic engineering. *Correlation is significant at the 0.05 level (2-tailed) (Q24 - Section A.2

		Familiar	Q24
Familiar	Correlation Coefficient	1.000	.155*
	Sig. (2-tailed)		.044
	N	171	171
Q24	Correlation Coefficient	.155*	1.000
	Sig. (2-tailed)	.044	
	N	171	171

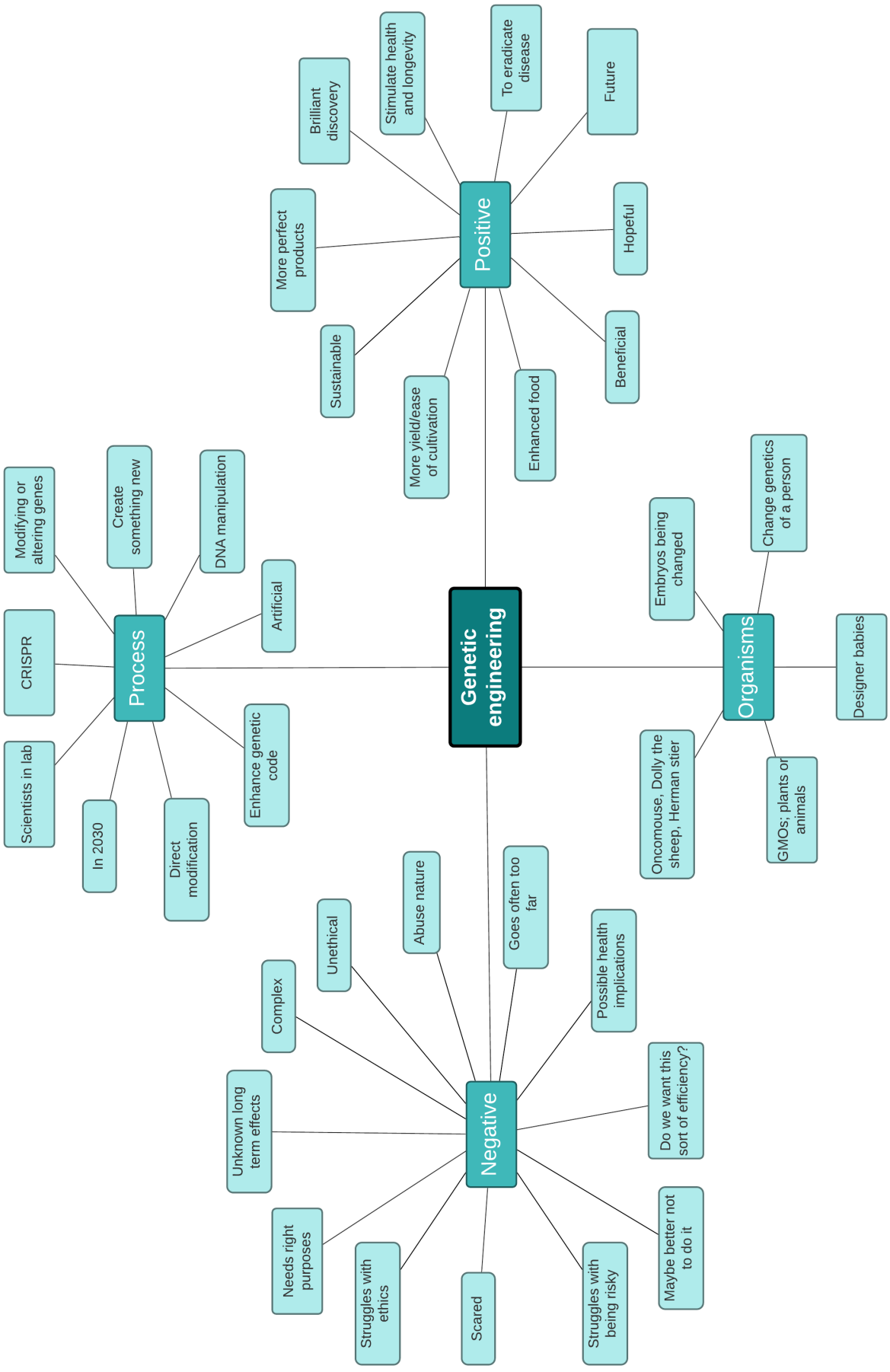


Figure A.2: A concept map from the answers to Q10 from the online-questionnaire. Categorized by the four specific labels: positive, negative, organisms, and process.

A.8 KRUSKAL–WALLIS TEST

Table A.6: Kruskal-Wallis H ranks with respective Q data as dependent ordinal variable and generation as the independent grouping variable. There is independence of observations.

Birth	N	Mean Rank Q21	Mean Rank Q22.1	Mean Rank Q22.2	Mean rank Q25
19-25	64	73.72	72.42	71.52	74.90
26-35	63	80.18	79.40	83.25	82.20
36-45	31	90.05	94.31	88.37	83.52
Total	158	158	158	158	

Table A.7: Kruskal-Wallis H test statistics results with respective Q data as dependent ordinal variable and generation as the independent grouping variable. There is independence of observations.

Variable	Q21	Q22.1	Q22.2	Q25
Chi-Square	3.474	5.013	3.681	1.385
df	2	2	2	2
Asymp.Sig.	.176	.082	.159	.500

A.9 MANN–WITHNEY U TEST

Table A.8: The Mann-Whitney U ranks and test statistics with independent grouping variable knowledge on micro-organisms (yes/no) and the ordinal variable responses to Q15. (Q15 - Section A.2)

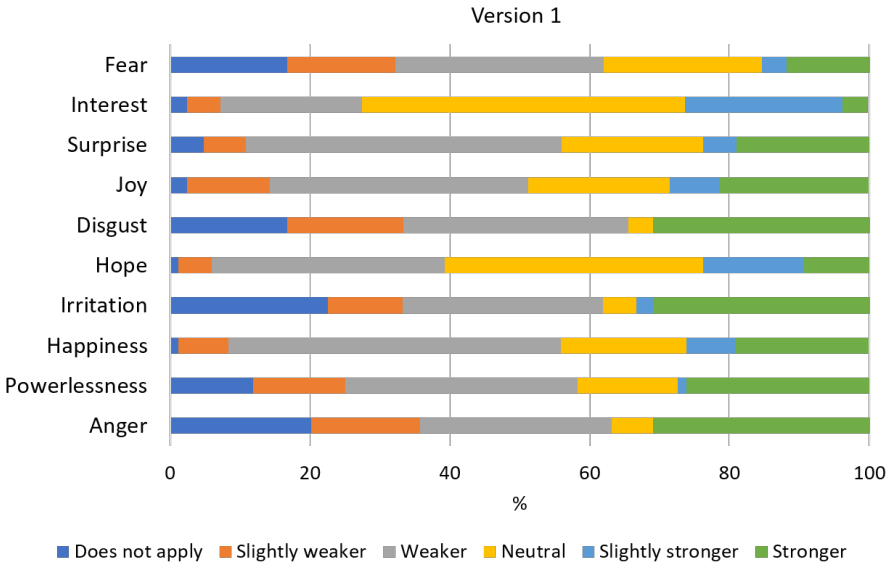
Knowledge	N	Mean Rank	Sum of Ranks	Test	Animals
Yes	158	85.55	13517.00	Mann-Whitney U	956.000
No	13	91.46	1189.00	Wilcoxon W	13517.000
Total	171			Z	-,483
				Asymp.Sig.(2-tailed)	.629
Knowledge	**N**	**Mean Rank**	**Sum of Ranks**	**Test**	**Micro-organisms**
Yes	158	84.76	13392.50	Mann-Whitney U	831.500
No	13	101.04	1313.50	Wilcoxon W	13392.500
Total	171			Z	-1.240
				Asymp.Sig.(2-tailed)	.215
Knowledge	**N**	**Mean Rank**	**Sum of Ranks**	**Test**	**Plants**
Yes	158	86.85	13722.00	Mann-Whitney U	893.000
No	13	75.69	984.00	Wilcoxon W	984.000
Total	171			Z	-.859
				Asymp.Sig.(2-tailed)	.390
Knowledge	**N**	**Mean Rank**	**Sum of Ranks**	**Test**	**Do not care**
Yes	158	87.09	13761.00	Mann-Whitney U	854.000
No	13	72.69	945.00	Wilcoxon W	945.000
Total	171			Z	-1.566
				Asymp.Sig.(2-tailed)	.117

Table A.9: The Mann-Whitney ranks and test statistics with independent grouping variables, medical food needed (yes/no) and the ordinal variable responses to Q24. (Q24 - Section A.2)

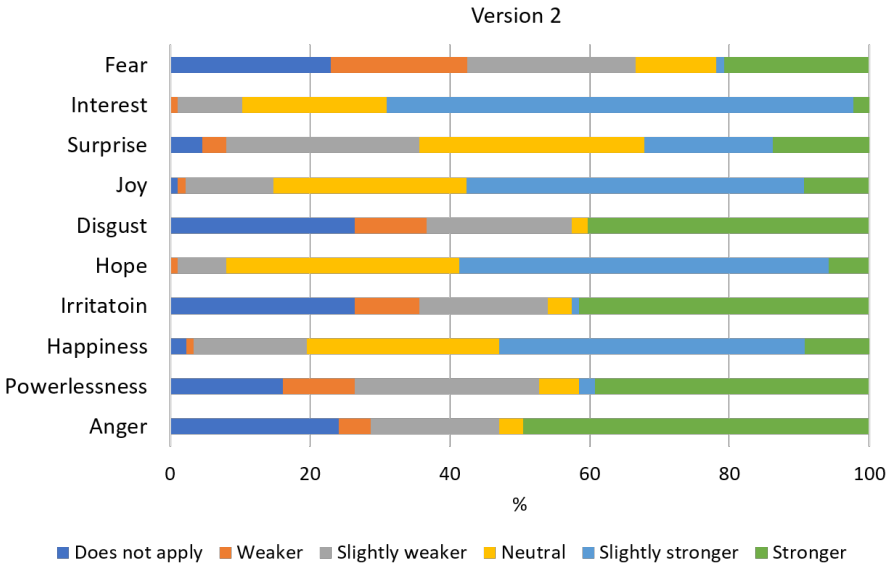
Medical food	**N**	**Mean Rank**	**Sum of Ranks**	**Test**	**Q24.1**
Yes	158	94.25	942.50	Mann-Whitney U	722.500
No	13	85.49	13763.50	Wilcoxon W	13763.500
Total	171			Z	-,569
				Asymp.Sig.(2-tailed)	.570
Medical food	**N**	**Mean Rank**	**Sum of Ranks**	**Test**	**Q24.2**
Yes	10	97.45	974.50	Mann-Whitney U	690.500
No	161	85.29	13731.50	Wilcoxon W	13731.500
Total	171			Z	-.825
				Asymp.Sig.(2-tailed)	.409
Medical food	**N**	**Mean Rank**	**Sum of Ranks**	**Test**	**Q24.3**
Yes	10	120.95	1209.50	Mann-Whitney U	455.500
No	161	83.83	13496.50	Wilcoxon W	13496.500
Total	171			Z	-2.496
				Asymp.Sig.(2-tailed)	.013
Medical food	**N**	**Mean Rank**	**Sum of Ranks**	**Test**	**Q24.4**
Yes	10	78.05	780.50	Mann-Whitney U	725.500
No	161	86.49	13925.50	Wilcoxon W	780.500
Total	171			Z	-.536
				Asymp.Sig.(2-tailed)	.592
Medical food	**N**	**Mean Rank**	**Sum of Ranks**	**Test**	**Q24.5**
Yes	10	117.65	1176.50	Mann-Whitney U	488.500
No	161	84.03	13529.50	Wilcoxon W	13529.500
Total	171			Z	-2.176
				Asymp.Sig.(2-tailed)	.030

Table A.10: The Mann-Whitney ranks and test statistics with independent grouping variables, allergies (yes/no) and the ordinal variable responses to Q24. (Q24 - Section A.2

Allergies	**N**	**Mean Rank**	**Sum of Ranks**	**Test**	**Q24.1**
Yes	25	94.30	2357.50	Mann-Whitney U	1617.500
No	146	84.58	12348.50	Wilcoxon W	12348.500
Total	171			Z	-,950
				Asymp.Sig.(2-tailed)	.342
Allergies	**N**	**Mean Rank**	**Sum of Ranks**	**Test**	**Q24.2**
Yes	25	88.40	2210.00	Mann-Whitney U	1765.000
No	146	85.59	12496.00	Wilcoxon W	12496.000
Total	171			Z	-.287
				Asymp.Sig.(2-tailed)	.774
Allergies	**N**	**Mean Rank**	**Sum of Ranks**	**Test**	**Q24.3**
Yes	25	85.16	2129.00	Mann-Whitney U	1804.000
No	146	86.14	12577.00	Wilcoxon W	2129.000
Total	171			Z	-.100
				Asymp.Sig.(2-tailed)	.921
Allergies	**N**	**Mean Rank**	**Sum of Ranks**	**Test**	**Q24.4**
Yes	25	92.62	2315.50	Mann-Whitney U	1659.500
No	146	84.87	12390.50	Wilcoxon W	12390.500
Total	171			Z	-.742
				Asymp.Sig.(2-tailed)	.458
Allergies	**N**	**Mean Rank**	**Sum of Ranks**	**Test**	**Q24.5**
Yes	25	103.78	2594.50	Mann-Whitney U	1380.500
No	146	82.96	12111.50	Wilcoxon W	12111.500
Total	171			Z	-2.030
				Asymp.Sig.(2-tailed)	.042



(a)



(b)

Figure A.3: Stacked bar charts of the respondents' distribution by version per change of emotional response in % (Q20). See Table 8.19 and Table 8.20 for the corresponding frequency tables.

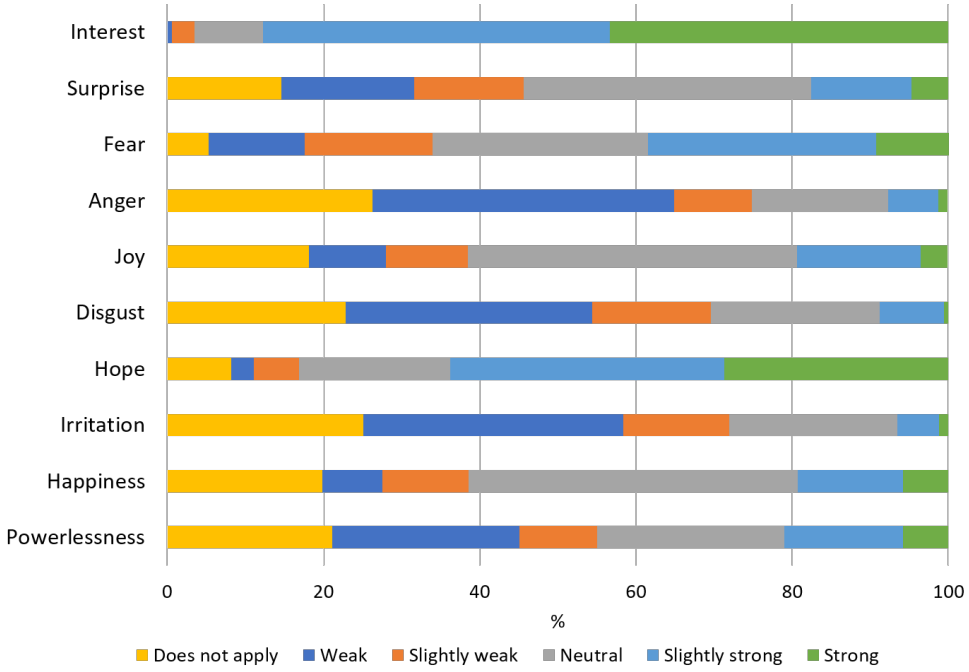


Figure A.4: Stacked bar chart of the respondents' distribution per emotional response in % (Q13). See Table 8.15 for the corresponding frequency table.

B APPENDIX 2

B.1 ARTICLES AND CODING

The codes in Table 5.1 were used to select and distinguish literature for this review.

Frewer et al. (2013) - Attitudes towards genetically modified animals in food production. (Frewer et al., 2014)

- **Purpose:** review on consumer acceptance issues.
- **Methodology:** systematic review of 42 papers followed by thematic analysis.
- **Findings:** publication peaked in 2004, declined thereafter. European consumers accepted technology more than US and Asian consumers. Ethical concerns explain negative consumer attitudes.
- **Gap:** methods to involve consumers and other stakeholders to track changes in public opinion and lack of data in developing countries.
- **Country:** summary of regions/countries.
- **Codes:** CP, L, TO, TC, Ex, RE, CI, T

Durnberger (2019) - Normative Concepts of Nature in the GMO Protest. A qualitative Content Analysis of Position Papers Criticizing Green Genetic Engineering in Germany. (Dürnberger, 2019)

- **Purpose:** complement existing interpretations by showing that emerging concepts of nature are more diverse. Promotes a descriptive approach of environmental ethics while normative works try to provide a justified answer to the question of how to act from a moral perspective, whereas descriptive gives a better understanding of the problem.
- **Methodology:** qualitative content analysis.
- **Findings:** emerging concepts are more diverse than the familiar reductionist breakdown of the debate into anthropocentric vs. non-anthropocentric conceptions suggests.
- **Gap:** how should the different concepts of nature which are essential to backdrop the controversy about GM, be dealt with? Pay attention to (c) of the proposals. Conflict management instruments and educational processes.

- **Country:** -
- **Codes:** Ex, In, RE, N, CP, CS

Ryland (2001) - Regulating Genetically Modified Organisms in the Interests of Whom? (Ryland, 2001)

- **Purpose:** to treat the regulation of GMO under European Community law.
- **Findings:** consumer confidence in the regulation of GMOs must be restored.
- **Gap:** the need for food products to be derived from GM is questioned.
- **Country:** -
- **Codes:** L, CI, R, RA

Gaivoronskaia and Solem (2001) - Managing risks in biotechnology: can we learn from nuclear power? (Gaivoronskaia and Solem, 2001)

- **Purpose:** can lessons be learnt from the introduction of nuclear power a generation ago?
- **Methodology:** literature review.
- **Findings:** science and government emphasize the social benefits of nuclear and biotechnologies in their efforts to popularize them.
- **Gap:** is there an organizational structure that might provide for both a technological solution and social accommodation? How to design a consultation process that addresses public concerns?
- **Country:** -
- **Codes:** RE, R, CP, T

Jones (1996) - Food biotechnology: current developments and the need for awareness. (Jones, 1996)

- **Purpose:** discuss current and future applications of GM in food industry.
- **Methodology:** literature review.
- **Findings:** initiatives to raise awareness among industry and consumers.
- **Gap:** wider debate on regulatory control and moral and ethical concerns.
- **Country:** -
- **Codes:** G, CP, T, CS

Frewer and Shepherd (1995) - Ethical concerns and risk perceptions associated with different applications of genetic engineering: interrelationships with the perceived need for regulation of the technology. (Frewer and Shepherd, 1995)

- **Purpose:** to compare public attitudes towards genetic engineering for two different applications (food vs. medicine).
- **Methodology:** questionnaires and standard definition of GM provided. Two sections: risk, benefit and control and ethical reasons. Analysis of variance and correlations.
- **Findings:** attitudes towards the application of GM are differentiated primarily by the nature of the application.
- **Gap:** both risk and ethical concern should be addressed in the legislative framework surrounding the technology.
- **Country:** UK
- **Codes:** E, Ex, In, ET, RE, TC, TO, CP, T, R

Verdurme and Viaene (2003) - Exploring and modelling consumer attitudes towards GM food. (Verdurme and Viaene, 2003)

- **Purpose:** to explore consumer beliefs, attitudes and purchase intentions of GM food and to develop a hypothetical model which can explain and predict consumer attitudes and purchase intentions.
- **Methodology:** qualitative research, group discussions with consumers and in-depth interviews (unstructured open-ended approach) with representatives of interested parties. Plus, literature research.
- **Findings:** research model to explain how consumer attitudes towards GM food are formed and how these attitudes affect purchase intentions.
- **Gap:** quantitative model testing by means of a consumer survey. Plus, quantitatively confirming that consumer attitudes towards premium GM food products is much more positive.
- **Country:** Belgium
- **Codes:** RE, CP, L, TC, TP, CS

Scully (2003) - Genetic engineering and perceived levels of risk. (Scully, 2003)

- **Purpose:** explores the role of consumers opinions, attitudes and behaviours towards GM. Focusing on the relative perceived risk associated with consuming GM food and the role of food labelling in reducing this risk.
- **Methodology:** door-to-door personal interviews, questionnaire with open-ended questions.
- **Findings:** beliefs rather than information appear to be at the heart of the non-acceptance of GM.
- **Gap:** effective risk communication strategy is needed to convey objective risk data with recognizing the role of consumers' beliefs in determining perceived risks.

- **Country:** NZ
- **Codes:** RE, CP, TC, L

Zhang et al. (2018) - Application of an integrated framework to examine Chinese consumers' purchase intention toward genetically modified food. (Zhang et al., 2018)

- **Purpose:** to examine consumers' purchase intention toward GM food by using benefit-risk analysis (BRA); (ii) to examine consumers' purchase intention toward GM food based on the theory of planned behavior (TPB); and (iii) to determine which framework or theory significantly influences the interpretation of purchase intention toward GM food under an integrated framework incorporating the BRA and the TPB.
- **Methodology:** online survey analysed by structural equation modeling.
- **Findings:** (i) BRA framework: Chinese consumers rely on their positive attitude toward GM food to increase purchase intention and their perceived risks to decrease purchase intention. Moreover, consumers' trust increases their perceived benefits offered by GM food and decrease their perceived risks; (ii) TPB framework: attitude toward GM technology is the most significant predictor of purchase intention toward GM food, followed by perceived behavioral control and subjective norms; and (iii) under the integrated framework, although most of the results in the single framework of the BRA or the TPB are supported, the BRA provides better interpretation than the TPB.
- **Gap:** studies that systematically examine empirical evidence and theoretical explanations of the purchase intention toward GM food are few. The integrated framework proposed in this study can be employed by other authors to systematically examine the attitude and purchase intention toward GM food. One type of consumer was considered (different consumers have different risk perceptions), only one degree of GM risk. Finally, other information resources, such as knowledge, emotions, individual attributes, and price, were not included in the integrated framework that used to examine perception of benefits and risks.
- **Country:** China
- **Codes:** CP, TC, T

Miles et al. (2005) - Public attitudes towards genetically-modified food. (Miles et al., 2005)

- **Purpose:** investigates the impact of information about traceability (labelling) for GM food on consumer attitudes and trust.
- **Methodology:** questionnaire with "information condition" or "no information condition".
- **Findings:** information about new detection methods did not influence consumer attitudes but an effective system did. People prefer to have all GM food labelled.

- **Gap:** different labels for processing aid or food additive?
- **Country:** Italy, Norway and England
- **Codes:** CP, L, TC, RE, CI, T, R

Hunt and Frewer (2001) - Trust in sources of information about genetically modified food risks in the UK. (Hunt and Frewer, 2001)

- **Purpose:** establishing the degree of trust the general public has in various possible sources of information about the health effects associated with consuming GM food.
- **Methodology:** questionnaire to test degree of familiarity after which reporting bias and degree of knowledge were tested. Chi-square test to "same" and all other responses.
- **Findings:** perceptions of "vested interest" and "degree of knowledge" are important elements in determining levels of trust. Plus, younger consumers are likely to be the most responsive audience for risk information, but general audience response to risk information is likely to be influenced by the source of information.
- **Gap:** establish what perceived health and environmental risks actually are, and the degree of concern people have about them. Perform trust and knowledge tests with different generations.
- **Country:** UK
- **Codes:** CP, T, CI

Knox et al. (2000) - Consumer perception and understanding of risk from food. (Knox, 2000)

- **Purpose:** brief historical overview of theories and approaches that have been applied to study risk perception.
- **Methodology:** literature review.
- **Findings:** models of food choice must incorporate the perception of risk as a decisional factor.
- **Gap:** private views of scientists, civil servants and industrialists. Risk perceptions require exploration within the social and cultural context. All parties involved in risk assessment and management forum need to be fully considered.
- **Country:** -
- **Codes:** CP, RA, RE, CS

Ellahi et al. (1996) - Genetic modification for the production of food: the food industry's response. (Ellahi, 1996)

- **Purpose:** evaluate food industry's behaviour in terms of company policy and attitudes towards GM foods. From food retailer and manufacturer's perspective.
- **Methodology:** qualitative approach - interviews with semi-structured questions. Send out in advance to those who granted an interview to allow the maximum use of interview time, and helped to develop the trust of the interviewee. The interviews were taped or recorded.
  Quantitative approach - (generation of numerical results for statistical analysis with large sample group size) analyse questionnaires with Likert scale questions by uni variate analysis and bivariate analysis to determine correlations.
- **Findings:** manufacturer's are less aware of the GM technique than retailers. Findings support the need for education on GM food.
- **Gap:** The question remains whether consumers are more likely to reject or be more in favor of GM food products as they become more aware of the issues and the technology itself. Knowledge low of labelling.
- **Country:** UK
- **Codes:** CP, TC, CI, R, L

Stemke (2004) - Genetically Modified Microorganisms. (Stemke, 2004)

- **Purpose:** describe biosafety and ethical issues on GM microorganisms.
- **Methodology:** literature study.
- **Findings:** information on many different aspects.
- **Gap:** emotions, underlying ethical concerns, and communication strategy.
- **Country:** -
- **Codes:** E, RE, RA, N, CP, L, CI

Saba et al. (1998) - Public concerns about general and specific applications of genetic engineering: a comparative study between the UK and Italy. (Saba et al., 1998)

- **Purpose:** to compare public concerns assessed by a combination of qualitative and quantitative analysis in the UK and Italy,
- **Methodology:** interviews and all respondents were given a standardized definition of GM before starting. Repertory grid method followed by generalised Procrustes analysis in two phases: (1) elicitation of constructs describing the concern about applications of GM (triadic presentation). (2) ratings of the applications on each construct (questionnaire).
- **Findings:** perceptions of need and benefit were important in both countries as determinants of acceptance. Negative constructs in Italy where more focused on ethical issues, whereas UK respondents also focused on risk-related issues.

- **Gap:** other countries.
- **Country:** Italy and UK
- **Codes:** CP, TC, RE, RA

Straughan (1990) - Genetic Manipulation for Food Production: Social and Ethical Issues for Consumers. (Straughan, 1990)

- **Purpose:** summarise and assess main arguments for and against GM of animals, plants and microbes in food industry and consumer interests.
- **Methodology:** literature study.
- **Findings:** try to answer questions, Is it safe?, Is it fair? and Is it natural?
- **Gap:** focus on micro-organisms.
- **Country:** -
- **Codes:** CP, E, RE, N, TO

Frewer et al. (1995) - Genetic engineering and food: what determines consumer acceptance? (Frewer et al., 1995)

- **Purpose:** overview of psychological mechanisms that are likely to influence consumer acceptance of GM food. Understand relationship between public attitudes towards technology and acceptance of its products.
- **Methodology:** semi-structured interviewing, formalized psychometric models (repertory grid method in combination with generalized Procrustes analysis) and extensive structured survey research.
- **Findings:** order in which products become available is critical and labelling provides control feeling. Effective communication strategies are needed to facilitate public understanding.
- **Gap:** effect of reduced cost and same quality? In comparison to costs, benefits such as health and environment lead to more acceptable modifications? Conjoint analysis to examine preferences for different tangible benefits. Development of effective communication strategies including recognition of social context.
- **Country:** -
- **Codes:** CP, E, RE, TC, T, R, L

Frewer et al. (1996) - Effective communication about genetic engineering and food. (Frewer et al., 1996)

- **Purpose:** discusses the importance of effective risk-benefit communication about GM in food production.

- **Methodology:** semi-structured interviewing, formalized psychometric models (repertory grid method in combination with generalized Procrustes analysis) and extensive structured survey research.
- **Findings:** risk-benefit communication is likely to require a different approach to that which has evolved from the communication of risk alone.
- **Gap:** there is a need to develop risk-benefit communication strategies to maximize the effectiveness of communication for technological evolution and development.
- **Country:** -
- **Codes:** CP, TC, T, CI, CS

Taebi (2017) - Bridging the Gap between Social Acceptance and Ethical Acceptability. (Taebi, 2017)

- **Purpose:** describe a method to bridge the gap between social acceptance and acceptability.
- **Methodology:** literature study.
- **Findings:** a method has been described following the Rawlsian wide reflective equilibrium theory.
- **Gap:** apply this method to GM.
- **Country:** -
- **Codes:** CP, E, RE

B.2 GMM PRODUCT CATEGORIES

1. Chemically defined purified compounds and their mixtures produced with GMMs in which both GMMs and newly introduced genes have been removed (e.g. amino acids, vitamins).

2. Complex products produced with GMMs in which both GMMs and newly introduced genes have been removed (e.g. most enzyme preparations); or from GMMs in which both GMMs and newly introduced genes are no longer present (e.g. cell extracts).

3. Products produced from GMMs in which GMMs capable of replication or of transferring newly introduced genes are not present; but in which newly introduced genes are still present (e.g. heat-inactivated starter cultures).

4. Products consisting of or containing GMMs capable of replication or of transferring newly introduced genes (e.g. live starter cultures). (EFSA, 2011b)

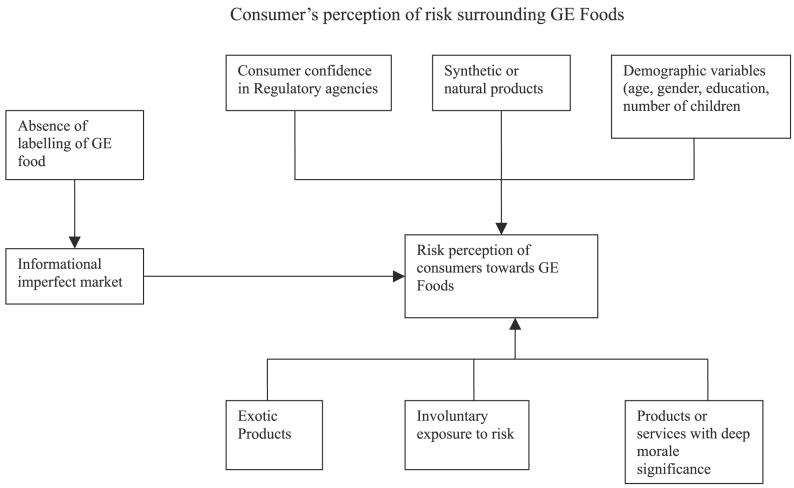


Figure B.1: Conceptual framework of the literature surrounding the risk perceptions of publics toward GM foods (Scully, 2003).

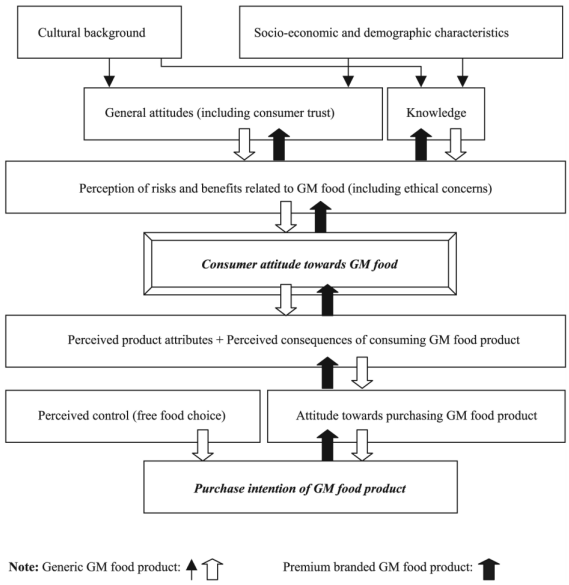


Figure B.2: Hypothetical model to explain public attitude and behavioural intention with regard to GM food (Verdurme and Viaene, 2003).

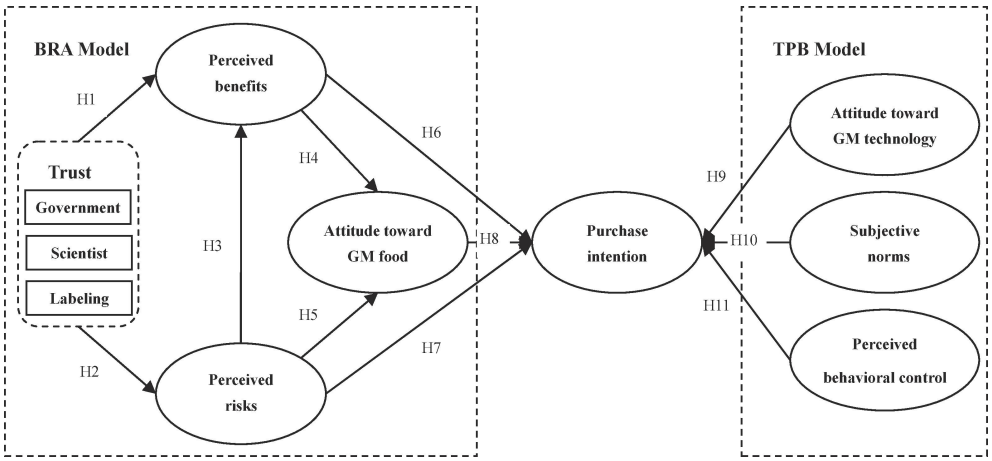


Figure B.3: Hypothetical model to examine the purchase intention towards GM food products by an integrated framework that incorporates the cost-benefit analysis (CBA) or benefit-risk analysis (BRA) with the theory of planned behavior (TPB). (Zhang et al., 2018).

COLOPHON

This document was typeset using LaTeX. The document layout was generated using the `arsclassica` package by Lorenzo Pantieri, which is an adaption of the original `classicthesis` package from André Miede.