The public opinion in Sweden on gene-edited crops and farmed animals

Genteknikнämnden
The Swedish Gene Technology Advisory Board

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Preface

The Swedish Gene Technology Advisory Board (Gentekniknämnden) is an authority tasked with promoting the responsible and safe use of gene technology. The Board is also responsible for informing policymakers and the public about current issues in the field of gene technology. As part of this work, the Board conducted this study in collaboration with the analysis company Novus. The aim was to better understand the Swedish public's attitude towards the use of gene editing techniques, such as the CRISPR/Cas9 gene scissors, in the agricultural sector.

The development of CRISPR/Cas9 has had a profound impact on the biosciences. One way the technology can be used is to enhance the breeding of crops and livestock for food production. This could give crops and animals with a lower environmental and climate footprint, but it also raises questions about ethics and how the legislation surrounding the use of this technology should be shaped. Therefore, it is of great importance to study the public opinion in this matter as that could be a factor which determines how a new technique like CRISPR/Cas9 will be used and regulated in the society. With two surveys we assessed the views on gene editing among people in Sweden, focusing on the applications crop breeding and breeding of farm animals.

The surveys were designed by Mia Olsson and Annelie Carlsbecker from the secretariat of the Swedish Gene Technology Advisory Board in discussion with Jens Sundström, Martin Weih, and Madeleine Zetterberg, experts from the Board, as well as Helena Björck and Daniela Lundgren from Novus. Novus carried out the surveys and compiled the results. The report was written by Mia Olsson and Annelie Carlsbecker. The authors would like to thank Dan Porsfelt from the Swedish Research Council for advice and assistance in designing the surveys, and Gunilla Elam for the illustrations.

Stockholm, 4 April 2025

The Swedish Gene Technology Advisory Board

Explanation of terms

Brief explanations of terms within the field of gene technology, as used in this report, are listed in this chapter. An introduction to breeding, gene technology, and legislation in this area can be found in Chapter 5.

Mutations are genetic changes that occur spontaneously in the DNA sequence and contribute to genetic variation between individuals, populations, and species. Mutations can also be induced by external factors, such as certain gene technologies or when DNA is damaged and then erroneously repaired by the cell's repair systems.

Mutagenesis is the process of inducing mutations.

Genome refers to the complete genetic makeup of an individual (all the DNA in a cell).

In **gene editing** (or genome editing), a mutation is induced at a predetermined location in an organism's genome. The techniques used are commonly referred to as genetic scissors. The most widely used gene editing technique today is CRISPR/Cas9. In plant breeding, gene editing is also known as targeted mutagenesis.

CRISPR/Cas9 is a molecular biology technique for gene editing, consisting of two components: an enzyme (Cas9) that cuts the double-stranded DNA and a guide-RNA that provides information about where the cut should be made. When the cell's repair system mends the DNA damage, a mutation sometimes occurs in the repair process. CRISPR is short for Clustered Regularly Interspaced Short Palindromic Repeats. The precursor to the technique is a viral defence system in bacteria and archaea.

In **random mutagenesis**, plants are treated with radiation or mutagenic substances to induce numerous mutations, which are randomly spread across the plant's genome. The plants that exhibit desirable breeding traits because of the treatment are then selected for further breeding.

In **transgenesis**, a new gene (DNA), is transferred into an organism's genome with the aim of changing an existing trait or introducing a new one.

In **cisgenesis**, a new gene (DNA) is transferred between individuals of the same species, or a between individuals of species able to crossbreed, with the aim of changing an existing trait or introducing a new one. The gene could also have been transferred through conventional crossbreeding.

A **Genetically Modified Organism (GMO)** is defined as "an organism in which the genetic material has been altered in a way that does not occur naturally through mating or natural recombination" in the EU legislation. GMOs include transgenic and cisgenic organisms as well as organisms modified through random or targeted mutagenesis (gene editing). EU legislation exempts organisms modified through random mutagenesis, but not those modified with new genomic techniques such as CRISPR/Cas9.

New Genomic Techniques (NGTs) is a term used for the gene technologies developed after the EU legislation on genetically modified organisms came into force in 2001. Gene editing with CRISPR/Cas9 is included in the group of NGTs.

Summary

Gene editing offers the opportunity to breed with precision, adapting crops and farm animals to a changing climate, providing disease resistance, faster growth, and more stable yields. Products from gene-edited crops and farm animals are introduced to markets outside the EU, and within the EU, negotiations are ongoing to relax the regulation of gene-edited plants. An interesting question is: how much does the Swedish public know about what gene editing entails, and what are their views on its use in agriculture?

To answer this question, two web-based surveys were conducted, focusing on gene-edited crops and farm animals, including farmed fish. About half of the respondents had previously heard of gene editing, and ten percent said they were somewhat or very familiar with the gene editing technology.

The majority were positive towards gene editing for most applications in crop breeding, provided the purpose was clearly beneficial to society, such as growing crops with a reduced negative impact on the environment or producing healthier food. Half of the respondents considered that it would be right to relax regulations for the approval of gene-edited crops within the EU, while just under a third thought it would be wrong.

If gene editing was to improve animal welfare, half of the respondents thought it would be right to use the technology for breeding farm animals. For other applications, there was more significant scepticism. Just over a third thought it would be right to relax legislation for gene-edited animals, while nearly half thought it would be wrong.

The study showed that younger individuals and those with greater knowledge of the technology were generally more positive. In comparison, older individuals and those who had not previously heard of gene editing were more negative. A greater understanding of what the technology involves correlated with a more positive attitude, with the central factor being whether the purpose benefited society.

1 Introduction

1.1 Gene editing in the agricultural sector

One of the most significant scientific breakthroughs of the 21st century is the development of CRISPR/Cas9 and similar gene editing techniques. With gene editing, researchers can precisely induce mutations in DNA, thereby altering the genetic code in living cells. The technique is also known as genome editing, and the induced mutations are no different from those that can occur spontaneously. Unlike older gene technologies, gene editing typically modifies existing DNA, and no new genes are introduced to change a trait.

Plant scientists can use gene editing in the agricultural sector to improve crops rapidly and efficiently. Gene editing can also be used in the breeding of livestock and farmed fish. Some countries have approved gene-edited crops for markets outside Europe. Japan has approved a gene-edited tomato with increased levels of the blood pressure-lowering compound GABA, the Philippines have approved a banana with reduced enzymatic browning and improved shelf life, and in the USA, lettuce that is less bitter and has improved nutritional content has been approved.[1] There is ongoing research and development on many different crops and breeding traits. In Sweden, for example, researchers are developing potatoes resistant to late blight and potatoes with altered starch composition.[2,3]

A few gene-edited livestock or farmed fish products are also available on markets outside Europe. Japan has approved two fast-growing fish species, and in the USA, a cow with a slick coat, which is better able to tolerate heat, has been approved. Colombia has approved a pig resistant to a severe viral disease. A significant number of research projects is also underway in this area. For example, Norwegian researchers have used gene editing to develop a sterile salmon adapted for aquaculture. The goal is for the salmon not to be able to reproduce and mix with wild salmon if it were to escape.

1.2 Laws govern the use of gene editing

As part of the EU's climate strategy, the Green Deal, gene editing techniques are highlighted as key contributions to ensuring food security and reducing the agricultural sector's negative impact on the environment and climate. At the same time, the EU has restrictive legislation that effectively prevents gene-edited crops and animals from entering the European market. The use of gene editing on crops and animals within the EU is regulated by legislation from 2001, which includes extensive requirements for risk assessment, detection methods, and labelling.

Outside the EU, many countries are changing their legislation and introducing relaxations for gene-edited crops, and, in some cases, also for animals used in food production.[4]

Within the EU, a legislative proposal is currently being negotiated to exempt gene-edited plants (but not animals) from the EU's existing legislation, provided the genetic changes made could also have occurred spontaneously or through conventional breeding.[5] The European Food Safety Authority (EFSA) has been tasked with analysing the potential risks of gene-edited farm animals to health and the environment, as a first step in evaluating whether the legislation should be reconsidered also for this area of use.

1.3 Does the public want gene-edited crops and animals?

Gene editing presents new opportunities but may also raise ethical concerns and questions about regulatory frameworks. How the public perceives emerging technologies, such as CRISPR/Cas9, may determine how, and to what extent, these are implemented in society. Consumer attitudes and willingness to purchase and consume gene-edited crops or animal-derived foods can have a direct impact on food production and availability. It is therefore important to analyse not only public attitudes towards these technologies, but also the level of public understanding, especially regarding applications that directly affect consumers.

In 2021, the Swedish Gene Technology Advisory Board and the analysis company Novus conducted a survey on the Swedish public's views on the use of gene editing and other techniques in crop breeding.[6] One conclusion from the study was that a majority were supportive of gene-edited crops, provided that the purpose was clearly beneficial to society. The survey also showed that the overall level of knowledge about gene technology and genetics was relatively low.

Attitude surveys carried out in other countries suggest that gene editing is often perceived as less risky and invasive than older techniques, such as classical transgenesis, where genes from other species are inserted into the plant or animal.[7–9] Research also indicates that there is generally higher acceptance of gene editing in plants than in animals.[10,11]

The rapid pace of technological development, combined with potential regulatory changes within the EU, makes it increasingly likely that gene-edited foods will enter the Swedish market. For this reason, it is essential to monitor both public understanding of and attitudes towards gene-edited crops and animals, as well as the factors influencing those views.

In this study, we focused on gene editing ana explored attitudes towards applications in both plants and animals. Participants were presented with concrete examples and intended purposes for gene editing. We also sought to gauge their willingness to act, that is whether they would consider consuming products derived from gene-edited plants and animals.

Insights into public attitudes can serve as a foundation for public awareness initiatives, and provide valuable information for policymakers and stakeholders.

2 Results

2.1 Half of the respondents had heard about gene editing

To analyse the Swedish public's attitudes towards gene-edited crops and animals, Novus conducted two survey studies on behalf of the Swedish Gene Technology Advisory Board. Each survey was completed by just over a thousand people from the Novus Sweden Panel, with a response rate of 53 percent. The Sweden Panel consists of individuals aged 18 to 79, with a broad demographic spread (see Chapter 4).

The first two questions were identical in both surveys and were designed to assess participants' prior knowledge of genetics and gene technology. As the results were very similar across the two surveys, they are presented combined in this report. In Question 1, participants were asked to self-assess their prior knowledge of gene editing. Based on their responses, subgroups were formed. The answers to subsequent questions were analysed in relation to these groupings.

Question 1.

How familiar are you with gene editing that is carried out by techniques such as the gene scissor CRISPR/Cas?

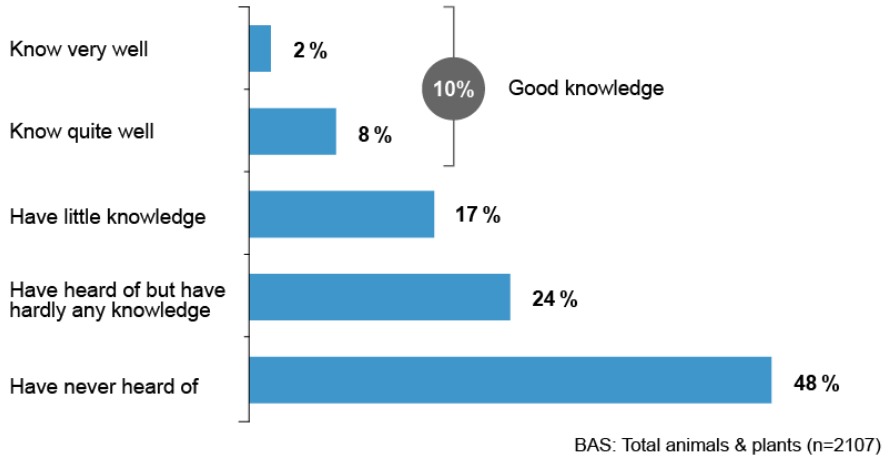


Figure 1. The combined responses from the plant and animal surveys to Question 1.

In total, 52 per cent had, to a different extent, heard of gene editing, while the remaining 48 per cent stated that they had never heard of it. One in ten answered they knew gene editing very well or quite well (2 and 8 per cent, respectively) and were grouped together under the label “those with good knowledge”. The ones who answered they know a little about gene editing was 17 per cent, while 24 per cent said they had heard of it but knew hardly anything about it (Figure 1).

Following the question on self-perceived knowledge of gene editing, the respondents’ actual knowledge of genetics and gene technology was assessed. They were presented with four statements and asked to indicate whether they knew the statement was correct, believed it was correct, believed it was incorrect, knew it was incorrect, or did not know.

Question 2a.

Research shows that genetically modified maize and soybeans are as safe to eat as their non-modified counterparts.

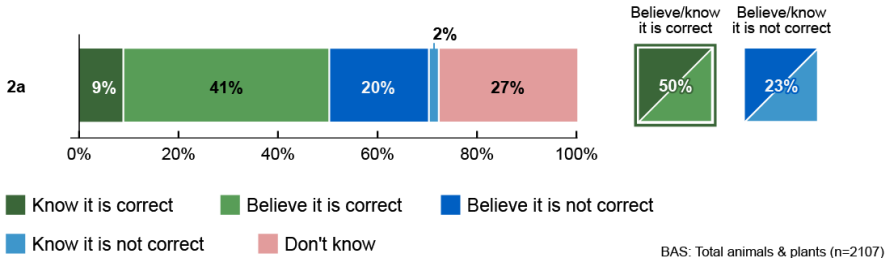


Figure 2a. The combined responses from the plant and animal surveys to Question 2a. The correct answer is that the statement is true, which has been highlighted with a frame around the “believe/know it is true” box in the image.

The statement that genetically modified maize and soybeans are safe to eat is correct, and 50 per cent of respondents indicated that they believe or know this to be true, although only 9 per cent were certain that it was true. Nearly a quarter, 23 per cent, incorrectly stated that the statement was false, with 2 per cent being confident in their response. More than a quarter, 27 per cent, answered “don’t know” (Figure 2a).

Question 2b.

With the gene scissor CRISPR/Cas, a modification to a gene can be introduced by cutting it at a predetermined location. When the cell repairs the gene, the genetic sequence is altered.

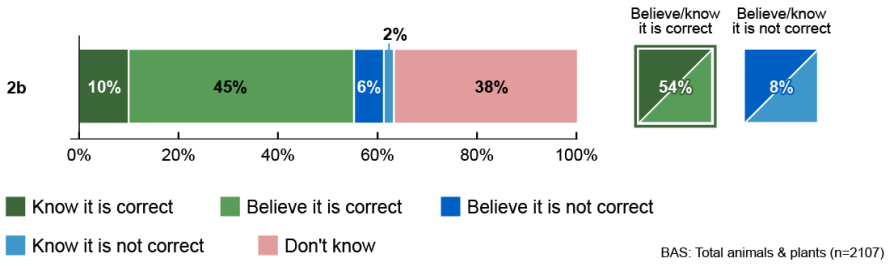


Figure 2b. The combined responses from the plant and animal surveys to Question 2b. The correct answer is that the statement is true, which has been highlighted with a frame around the "believe/know it is true" box in the image.

The statement is an accurate description of how CRISPR/Cas works, and more than half, 54 per cent, answered that the statement is true, with 10 per cent indicating that they know it is true. A small share, 8 per cent, of respondents said the statement is false, with 2 per cent being confident in their response. Nearly two in five, 38 per cent, answered "don't know" (Figure 2b).

Question 2c.

Tomatoes contain mostly carbohydrates and water but no DNA.

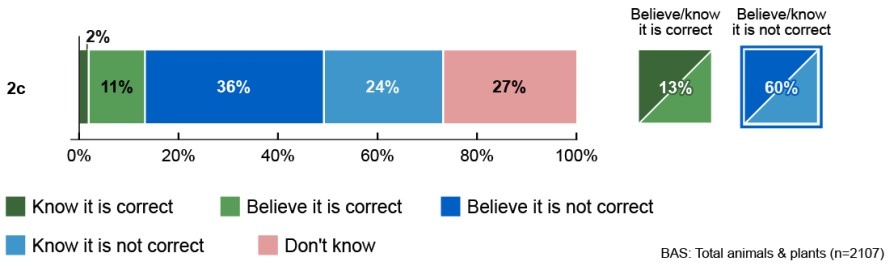


Figure 2c. The combined responses from the plant and animal surveys to Question 2c. The correct answer is that the statement is false, which has been highlighted with a frame around the "believe/know it is false" box in the image.

This is an incorrect statement, as tomatoes contain DNA, like all other living organisms. A majority of the participants, 60 per cent, recognised this and answered that the statement was false, with 24 per cent indicating that they knew it was false. A smaller proportion, 13 per cent, incorrectly stated that the statement was true, while 27 per cent answered, "don't know" (Figure 2c).

Question 2d.

It is common for food products sold in Swedish grocery stores to contain ingredients from genetically modified crops.

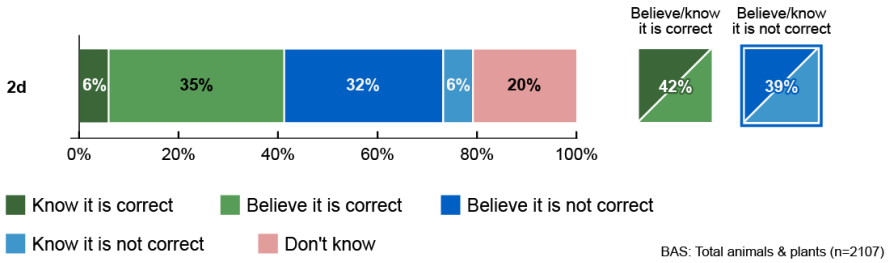


Figure 2d. The combined responses from the plant and animal surveys to Question 2d. The correct answer is that the statement is false, which has been highlighted with a frame around the "believe/know it is false" box in the image.

The statement that products based on genetically modified crops are common in Swedish grocery stores is false, but a large proportion, 42 per cent, incorrectly stated that it is true. Of these, 6 per cent were confident in their answer. The correct answer that the statement is false was given by 39 per cent, with 6 per cent confident in their response. One in five, 20 per cent, answered "don't know" (Figure 2d).

Uncertainty was evident among the survey participants regarding all four statements. Throughout, more respondents answered that they believed that the different statements were true/false than those that were certain, and between 20–38 per cent answered "don't know" to the knowledge-based questions.

2.2 Gene-edited crops – the Swedish public's attitude

After the knowledge-related questions, a brief description of gene editing was provided (Fact box 1).

Fact box 1. Information text in the plant survey

With the CRISPR/Cas technique, a gene can be modified in a crop to change a particular trait. This is called gene editing, and it is the crop's own genes that are altered. No new gene needs to be introduced into the crop's genetic material.

Below follows four examples of current research where gene editing has been used to develop a crop. What is your opinion?

2.2.1 Four examples of gene-edited crops

Following the information text, four examples of crops that have been bred and given new traits through gene editing were provided. All examples are taken from the scientific literature and therefore represent concrete examples of crops that a consumer might find in the Swedish grocery store in the future. The examples were presented in different orders to the participants, who were asked whether they believed it was completely or partially right, or completely or partially wrong, to gene-edit the crop to introduce the specified trait. The participants were also asked whether they would consider eating the crop or not.

Question 3. Potatoes with resistance to late blight

Using gene editing, a new potato variety has been developed that is resistant to late blight. As a result, it does not need to be treated with pesticides at all, or much less than other potato varieties. The potato does not look or taste different from a potato that has not been gene-edited.

a) Do you think it is right or wrong to modify one of the potato's genes to make it resistant to late blight?

b) Would you be willing to eat the gene-edited potato?

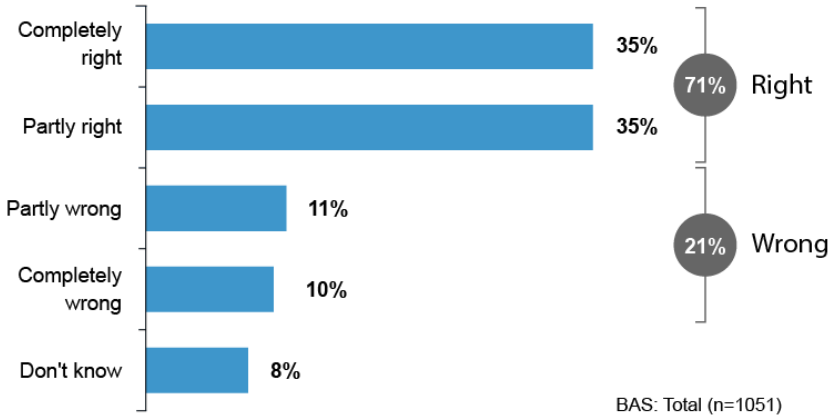


Figure 3. Responses to Question 3a in the plant survey.

A majority of the participants, 71 per cent, believed that it is right to use gene editing to develop a potato resistant to late blight, with 35 per cent stating that it is completely right. In contrast, 21 per cent said it is wrong, with 10 per cent stating that it is completely wrong. 8 per cent answered, "don't know" (Figure 3).

When asked if they would consider eating the gene-edited potato, 51 per cent answered "yes", 29 per cent "maybe", and 12 per cent "no". Again, 8 per cent answered, "don't know" (Figure 7).

Question 4. Shorter maize resistant to strong winds

Using gene editing, a new variety of maize has been developed that is shorter than regular maize. The shorter maize plants stand more firmly in strong winds and are less likely to break. The gene-edited maize looks and tastes no different from maize that has not been gene-edited.

a) Do you think it is right or wrong to modify genes in maize to make it more robust?

b) Would you be willing to eat the gene-edited maize?

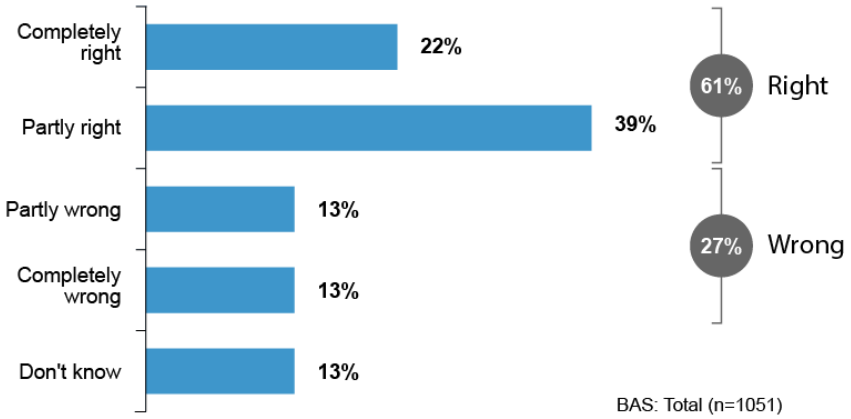


Figure 4. Responses to question 4a in the plant survey.

A majority of the participants, 61 per cent, believed that it is right to use gene editing to develop a shorter maize variety, with 22 per cent stating that it is completely right. In contrast, 27 per cent said it is wrong, with 13 per cent stating that it is completely wrong and 13 per cent answered, "don't know" (Figure 4).

When asked if they would consider eating the gene-edited maize, 43 per cent answered "yes", 28 per cent "maybe", and 16 per cent answered "no". A small share, 9 per cent, stated they "don't know" and 4 per cent said they do not eat maize (Figure 7).

Question 5. Vitamin D-enriched tomato

Using gene editing, a new variety of tomato has been developed that has high levels of vitamin D. The tomato looks and tastes no different from a tomato that has not been gene-edited

a) Do you think it is right or wrong to modify the tomato's genes to increase its vitamin D content?

b) Would you be willing to eat the gene-edited tomato or ketchup made from it?

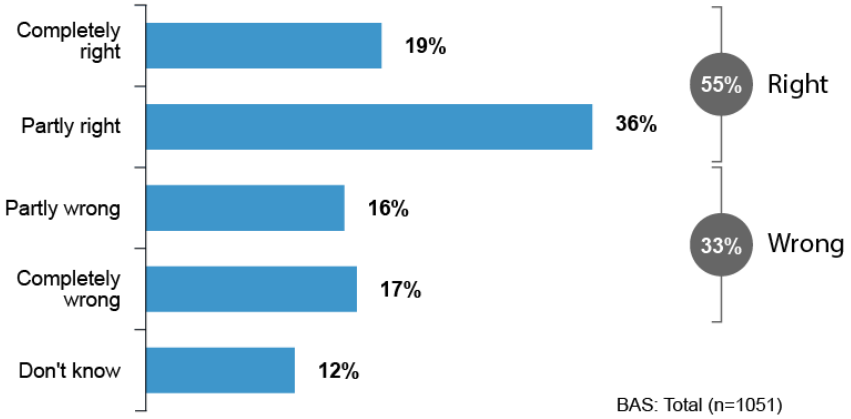


Figure 5. Responses to question 5a in the plant survey.

Just over half, 55 per cent, considered that it is right to use gene editing to develop a tomato enriched with vitamin D, with 19 per cent stating that it is completely right. A third, 33 per cent, believed the opposite, that it is wrong, with 17 per cent stating that it is completely wrong and 12 per cent answered, "don’t know" (Figure 5).

When asked if they would consider eating the gene-edited tomato, 41 per cent answered “yes”, 29 per cent “maybe”, and 19 per cent “no”. A smaller share, 10 per cent answered, "don’t know" and 1 per cent said they do not eat tomatoes or ketchup (Figure 7).

Question 6. Purple carrot

Using gene editing, a new variety of carrot has been developed that is purple in colour. Aside from its colour, the carrot looks and tastes no different from a carrot that has not been gene-edited.

a) Do you think it is right or wrong to modify the carrot's genes to make it purple?

b) Would you be willing to eat the gene-edited carrot?

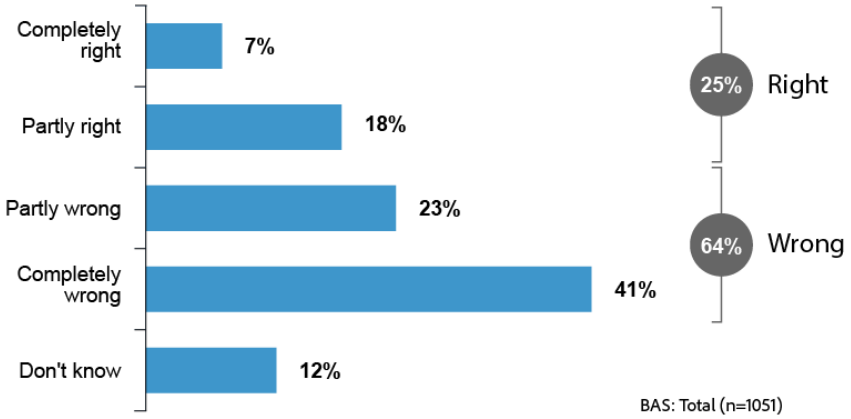


Figure 6. Responses to question 6a of the plant survey.

A quarter, 25 per cent, believed that it is right to gene-edit a carrot to make it purple, with 7 per cent stating that it is completely right. A majority, 64 per cent, believed the opposite, that it is wrong, with 41 per cent stating that it is completely wrong and 12 per cent answered, "don't know" (Figure 6).

When asked if they would consider eating the gene-edited carrot, 29 per cent answered "yes", 29 per cent "maybe", and 32 per cent "no". A small share, 8 per cent, answered "don't know" and 2 per cent said they do not eat carrots (Figure 7).

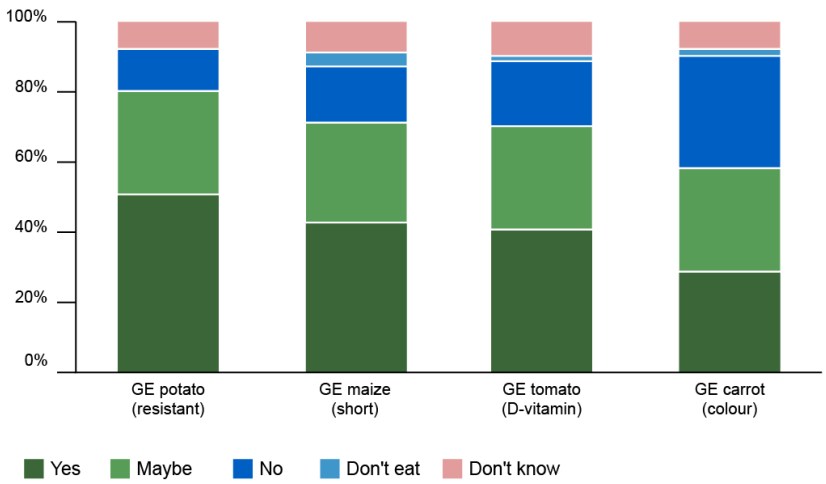


Figure 7. Responses to questions 3b, 4b, 5b and 6b in the plant survey, showing the proportions of respondents who would or would not consider eating the gene-edited crops in questions 3–6. (GE = gene-edited)

The Swedish public is relatively positive towards gene edited crops. In three out of four examples (questions 3–5), a majority answered that it is completely or partly right, 41–51 per cent said "yes" to the question of whether they would consider eating the resulting products, and a further 28–29 per cent answered "maybe".

2.2.2 The purpose of gene editing influences attitudes

In Questions 3–6, four examples of gene-edited crops were given, each with different traits modified to achieve various purposes. In several of the examples, the overall purpose was implicit and could be interpreted as reducing environmental impact, increasing yield, improving nutritional content, or simply changing the colour. It is difficult to know how the respondents interpreted the purpose, but the variation in attitudes towards the different examples suggests that the purpose may influence people's views.

To further analyse the importance of the overall purpose of gene editing for participants' attitudes, an additional question was asked and a few possible overarching purposes were specified. Respondents could agree with one or more of the alternatives, or indicate that they always think it is wrong, have no opinion, or do not know. The alternatives beginning with "It is right if …" appeared in a different order for different respondents.

Question 7. The purpose of using gene editing

Does the purpose of gene editing affect your opinion on whether you think it is right or wrong to use the technology to develop crops with new traits? (multiple answers possible)

a) It is right if it can contribute to secure food supply.

b) It is right if it can contribute to reducing the negative effects of agriculture on the environment and climate.

c) It is right if it can contribute to increase Swedish competitiveness in agricultural production.

d) It is right if it can contribute to higher incomes to farmers.

e) It is right if it can contribute to increase the range of plant-based products in grocery stores.

f) It is always wrong.

g) No opinion.

h) Don't know.

Overall, 77 per cent of respondents believed it is right to gene-edit crops for one of the proposed purposes described in options a-e, while only 11 per cent responded that it is always wrong to gene-edit crops. A smaller proportion indicated that they had no opinion (5 per cent) or answered, "don't know" (8 per cent).

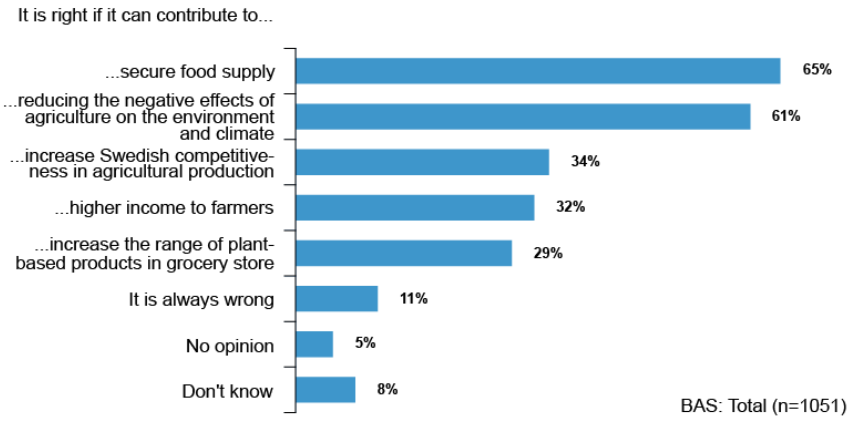


Figure 8. Responses to Question 7 in the plant survey.

A majority, 65 per cent, believed it is right to use gene editing to develop crops if it can help secure food supply. Nearly as many, 61 per cent, answered that it is right if the purpose is to reduce the negative impact of agriculture on the environment and climate.

About one-third thought it is right to use gene editing in plant breeding if it can increase Swedish competitiveness in agriculture or provide farmers with higher incomes (34 and 32 per cent, respectively). When the purpose is to increase the supply of plant-based products in grocery stores, 29 per cent thought it was right.

The purpose of gene editing in crops is important for the respondents' attitudes. A majority supported a purpose that benefits society or protects the environment and climate (Figure 8).

2.2.3 Changing the crop's own DNA more acceptable than introducing new DNA

Gene editing with CRISPR/Cas9 can be performed in different ways. The most common approach, where the existing DNA is modified and no new DNA is introduced, is employed in the examples for questions 3–6. However, the technology also makes it possible to insert new DNA at a specific site in the genome, such as a gene from the same species (cisgenesis) or from another species (transgenesis). Question 8 explored participants' attitudes towards these different approaches.

Question 8. Approach

Gene editing can be used to modify the crop's own genes in a way that could also occur spontaneously. The technique can also be used to introduce a new gene variant from a variety of the same species. For example, a gene variant that makes potatoes resistant to late blight. This gene variant could also have been transferred through crossbreeding from one potato variety to another. The technology also makes it possible to introduce a gene from an entirely different species.

Do you think it is right or wrong to use gene editing in these different ways? (Several responses are possible.)

a) It is right to modify a crop's genes in a way that could also occur spontaneously.

b) It is right to introduce a gene variant from a closely related crop.

c) It is right to introduce a gene from another species.

d) It is always wrong to modify a crop's genes using gene technology.

e) No opinion.

f) Don't know.

Overall, 52 per cent of respondents stated that it is right to use gene editing in one or more of the proposed ways, while 14 per cent said that it is always wrong to alter a crop's genes. Nearly one in five, 19 per cent, answered "don't know," and 14 per cent had no opinion.

Almost half, 46 per cent, said it is right to use gene editing if the crop's own DNA is altered.

Thirty-one per cent considered it right to introduce DNA from a closely related crop, and 18 per cent thought it was right to introduce DNA from a different species (Figure 9).

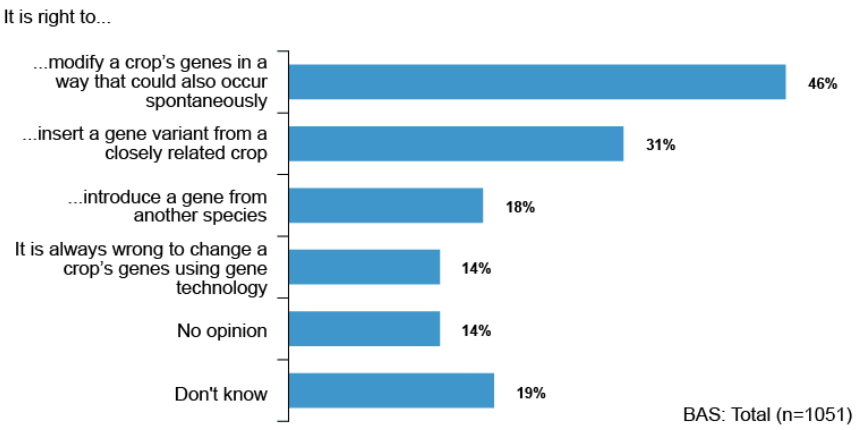


Figure 9. Responses to Question 8 in the plant survey.

In conclusion, participants had a more positive attitude towards altering existing DNA with gene editing compared to introducing new DNA, particularly if it came from another species.

2.2.4 One in two are positive to new EU law on gene-edited crops

A legislative proposal is being negotiated within the EU that would exempt gene-edited plants from the current legislation governing genetically modified organisms (GMO legislation) if the genetic changes made could also have been achieved using conventional breeding techniques. What is the public's opinion on such a change to the law?

Question 9. New proposed legislation for gene-edited crops

Whether a crop's own genes are modified through gene editing or a gene from another species is introduced, the crop is classified as a genetically modified organism (GMO) under EU regulations. GMOs are subject to very strict legislation in the EU. In practice, this means that the new varieties of potatoes, maize, tomatoes, and carrots described in the previous questions do not reach the European market.

Outside the EU, some countries are changing their legislation so that gene-edited crops are not classified as GMOs, provided that no genes from another species are introduced.

Do you think it would be right or wrong if the EU were to change its legislation so that gene-edited crops can be grown and sold in grocery stores?

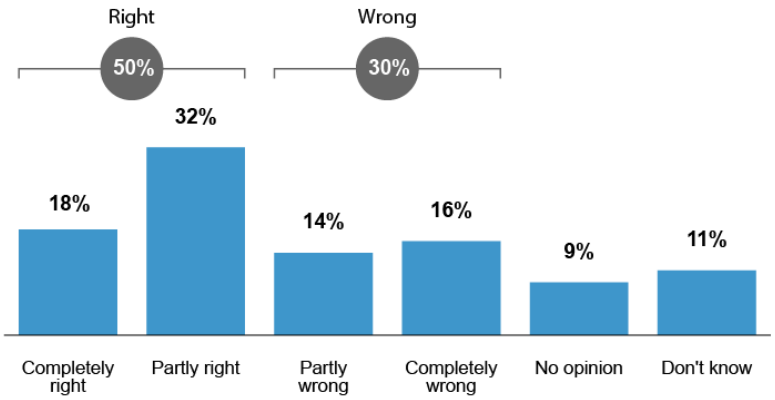


Figure 10. Responses to Question 9 in the plant survey.

Half of the participants, 50 per cent, believed that it would be right if EU legislation was changed so that gene-edited crops could reach the market, with 18 per cent stating that they thought it was completely right. Conversely, 30 per cent answered that it would be wrong, with 16 per cent of them saying it would be completely wrong to change the legislation. Just over one in ten, 11 per cent, answered "don't know," and 9 per cent stated that they had no opinion on the matter (Figure 10).

2.3 Gene-edited animals – the Swedish public's opinion

A brief description was provided on how gene editing can be used in the context of breeding farm animal (Fact box 2).

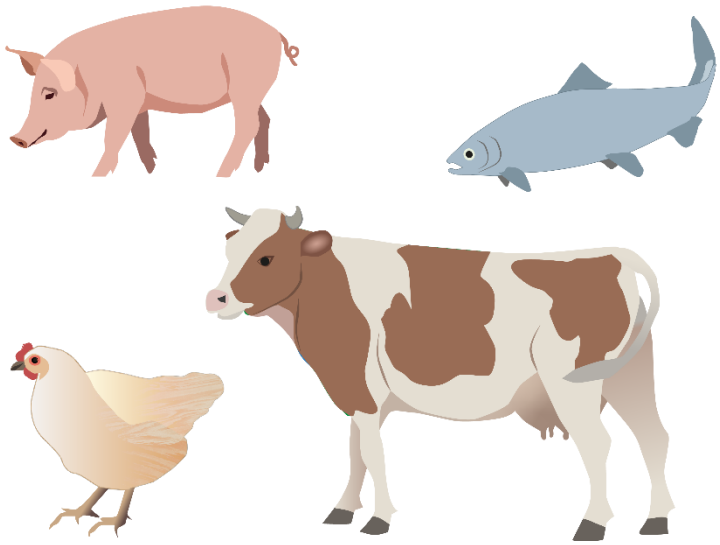
Fact box 2. Information text in the animal survey

With the CRISPR/Cas technique, a gene in an animal can be changed so that a trait is altered. This is called gene editing, and it is the animal's own genes that are altered. No new gene needs to be introduced into the genome of the animal.

Below are four examples of research currently being conducted, where gene editing has been used to develop new breeding lines of livestock. What is your opinion?

2.3.1 Four examples of gene edited animals

After the information text, four questions followed about different animals that have been bred and had their traits changed using gene editing. All examples were taken from the scientific literature and represent concrete examples of animal-based foods that a consumer might encounter in the future in Swedish grocery stores. The examples were presented in different orders to the participants, who were asked whether they believed it was completely or partially right, or completely or partially wrong, to gene-edit the animal to introduce the specified trait. The participants were also asked whether they would consider eating products from the animal or not.



Question 3. Pigs resistant to viral disease

Using gene editing, pigs that are resistant to a viral disease have been bred. The gene-edited pigs do not look different, and the meat does not taste different compared to meat from another pig.

a) Do you think it is right or wrong to use gene editing to modify a gene to breed pigs that are resistant to the viral disease?

b) Would you be willing to eat meat from the gene-edited pigs?

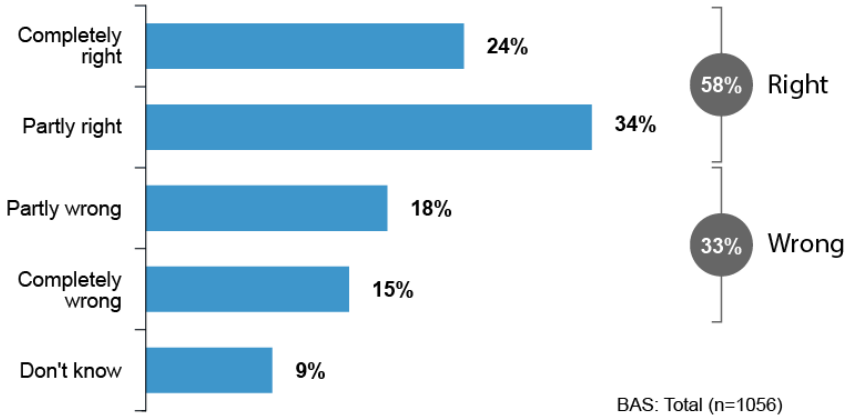


Figure 11. Responses to Question 3a in the animal survey.

The majority, 58 per cent, thought that it is completely or partly right to use gene editing in breeding of pigs resistant to the viral disease, with 24 per cent answering that it is completely right. One-third, 33 per cent, thought it was wrong, with 15 per cent answering that it is completely wrong. Nine per cent answered, "don't know" (Figure 11).

When asked whether they would be willing to eat meat from the gene edited pigs, 35 per cent answered "yes", 26 per cent "maybe", and 23 per cent "no". A small share, 8 per cent, answered "don't know" and an equal proportion said they do not eat pork (Figure 15).

Question 4. Cattle without horns

Using gene editing, cattle that do not grow horns have been bred. In Sweden, horn buds are burned off calves to prevent them from injuring each other or humans. Apart from the lack of horns, the cattle do not look different, and the milk does not taste any different from milk from other cows.

a) Do you think it is right or wrong to use gene editing to modify a gene to breed cattle without horns?

b) Would you consider eating dairy products from the gene-edited cows?

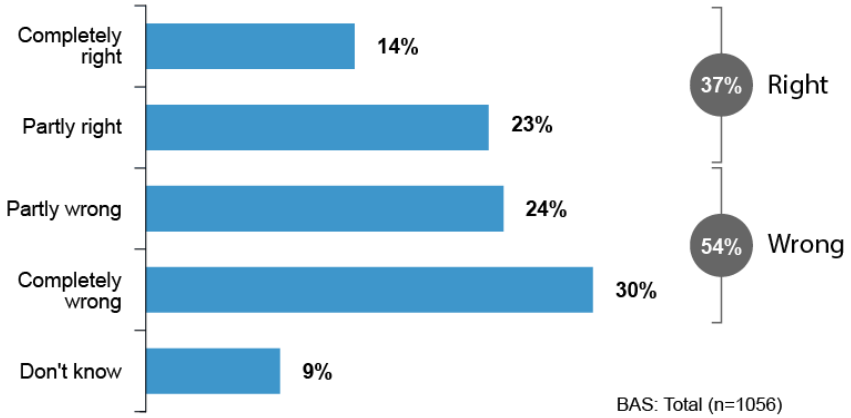


Figure 12. Responses to Question 4a in the animal survey.

The proportion that answered that it is completely or partly right to gene edit cattle so that they do not develop horns was 37 per cent, with 14 per cent answering that it is completely right. A majority, 54 per cent, thought it was completely or partly wrong, with 30 per cent answered that it was completely wrong. 9 per cent answered, "don't know" (Figure 12).

When asked whether they would be willing to eat dairy products from these cows, 35 per cent answered “yes”, 25 per cent “maybe”, and 28 per cent “no”. A tiny share, 2 per cent, said they do not eat dairy products, and 10 per cent answered, "don't know" (Figure 15).

Question 5. Fish with more muscle mass

Using gene editing, a fish that develops 20 per cent more muscle mass has been generated. This means that each fish provides more food. The fish does not otherwise look or taste different.

a) Do you think it is right or wrong to use gene editing to modify a gene to breed fish that produces more muscle mass?

b) Would you be willing to eat the gene-edited fish?

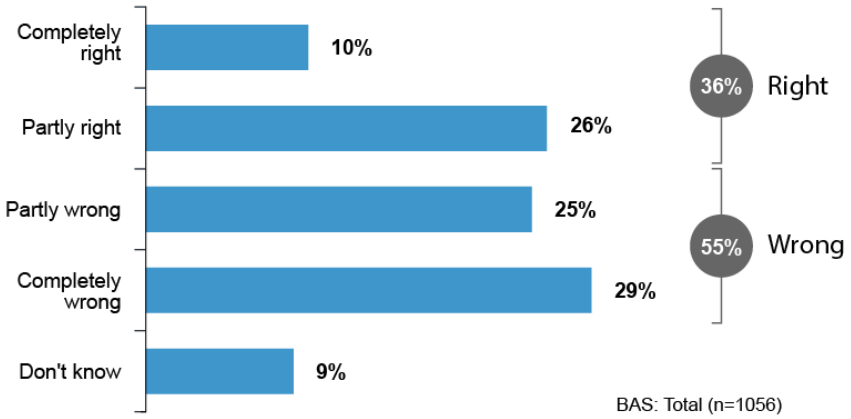


Figure 13. Responses to Question 5a in the animal survey.

Those who answered that they thought it was completely or partially right to gene-edit fish for increased muscle mass were 36 per cent, of which 10 per cent answered it was completely right. A majority, 55 per cent, believed it was completely or partially wrong, with 29 per cent answering it was completely wrong and 9 per cent answered, "don't know" (Figure 13).

Nearly a quarter, 24 per cent, would be willing to eat the gene-edited fish, 29 per cent answered “maybe”, and 33 per cent “no”. A smaller proportion, 5 per cent, stated that they do not eat fish, and 9 per cent answered, "don't know" (Figure 15).

Question 6. Hens laying allergy-friendly eggs

Using gene editing, hens that lack the substance that people suffering from egg allergy react to have been bred. This means that most people with egg allergy can eat the eggs. The hens do not look different, and the eggs taste as usual.

a) Do you think it is right or wrong to use gene editing to modify a gene to breed hens whose eggs can be eaten by persons who are allergic to eggs?

b) Would you be willing to eat the eggs?

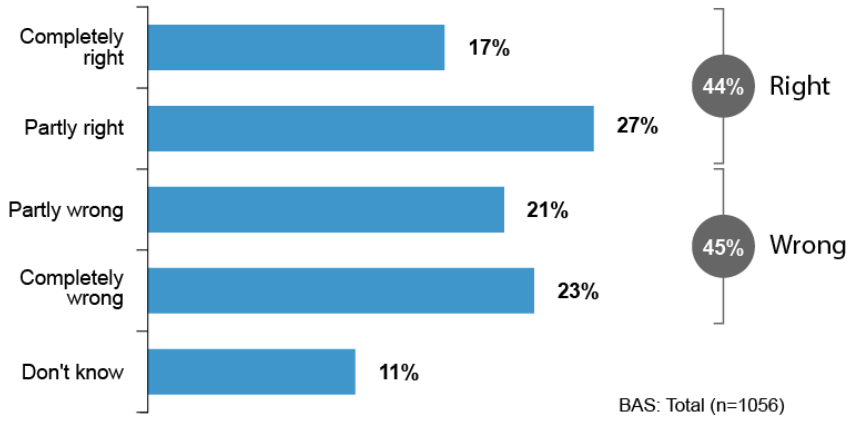


Figure 14. Responses to Question 6a in the animal survey.

Those who answered that it is completely or partly right to gene edit hens to obtain eggs that can be eaten by people allergic to eggs were 44 per cent, with 17 per cent stating that they thought it was completely right. A nearly equal proportion, 45 per cent, thought that it was completely or partially wrong, with 23 per cent stating that it was completely wrong and 11 per cent answered, "don't know" (Figure 14).

When asked whether they would be willing to eat eggs from gene-edited hens, 30 per cent answered “yes”, 28 per cent “maybe”, and 31 per cent “no”. Nearly one in ten, 9 per cent, answered "don't know," and 2 per cent stated that they do not eat eggs (Figure 15).

Overall, the Swedish public appear sceptical about using gene editing on farm animals. A small majority had a positive attitude towards one out of four examples of gene-edited animals, but for the other examples, people were mostly negative. Around a third of participants responded “yes” to whether they could be willing to eat products from the gene-edited animals, 24–35 per cent, and 25–29 per cent responded “maybe” (Figure 15).

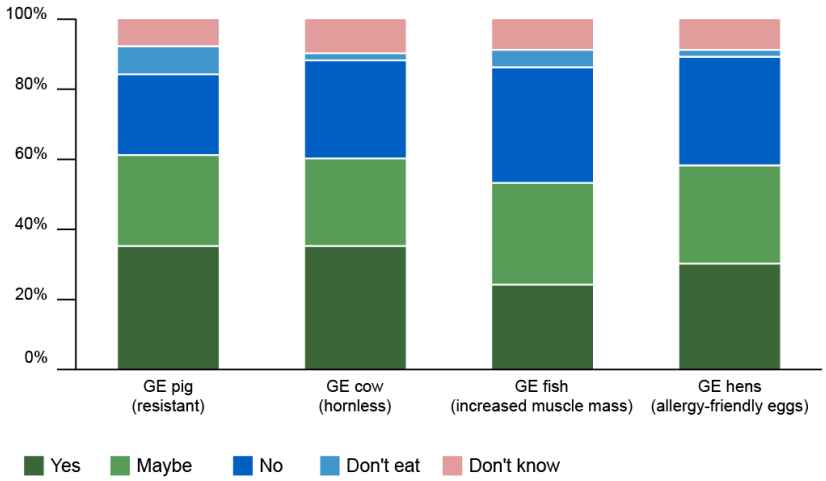


Figure 15. Responses to Questions 3b, 4b, 5b, and 6b in the animal survey, showing the proportions of participants who would be willing to eat or not willing to eat products from the gene-edited animals in Questions 3–6. GE = gene edited.

2.3.2 Gene Editing to Improve Animal Welfare Most Accepted

In Questions 3–6, the broader goals of gene editing were not explicitly expressed. It was not stated whether the purpose, for example, relates to improved animal welfare, sustainability, or profitability, but the examples were chosen to represent different potential goals. We cannot be sure about how the respondents interpreted the examples. Therefore, an additional question was asked, where several possible overarching purposes of gene editing in animals were suggested.

Respondents could select one or more of the options beginning with "it is right if..." or indicate that gene editing of animals is always wrong, that they had no opinion or did not know. The options a-e were presented in a different order for each respondent.

Question 7. The purpose of using gene editing

Does the purpose of gene editing affect your opinion on whether it is right or wrong to use the technology to breed livestock with new traits? (multiple answers possible)

a) It is right if it can contribute to increased animal welfare in the agricultural sector.

b) It is right if it can contribute to reducing the negative effects of agriculture on the environment and climate.

c) It is right if it can contribute to a secure food supply.

d) It is right if it can contribute to give higher incomes to farmers.

e) It is right if it can contribute to increased Swedish competitiveness in agricultural production.

f) It is always wrong.

g) No opinion.

h) Don’t know.

A total of 67 per cent of respondents stated that they believed it is right to use gene editing on animals for at least one of the proposed purposes listed in options a–e, while 19 per cent stated that it is always wrong to gene edit animals. A small proportion, 5 per cent, had no opinion, and 9 per cent answered "do not know".

Just over half, 52 per cent, answered that it is right to use gene editing on animals if it can help improve animal welfare in the agricultural sector.

Those who believed it is right if the purpose is to reduce the negative effects of agriculture on the environment and climate amounted to 44 per cent, and 40 per cent responded that it is right if it helps secure food supply.

If the aim was to benefit the farmer through increased income or to strengthen Swedish competitiveness, 18 per cent in both cases answered that it is right.

Those who stated that it is always wrong to use gene editing in livestock breeding were 19 per cent. A few, 5 per cent, said they had no opinion, and 9 per cent answered "do not know" (Figure 16).

It is clear that the purpose of gene editing in animals significantly influences respondents' attitudes. Only when the primary aim is to improve animal welfare did a slight majority believe that using the technology is right.

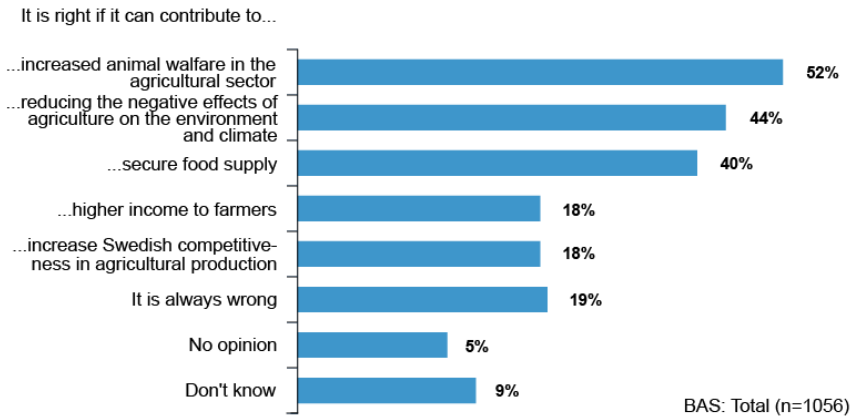


Figure 16. Responses to Question 7 in the animal survey.

2.3.3 Modifying the animal's own DNA more accepted than introducing new DNA

Gene editing can be used in different ways. The most common approach, where the existing DNA is modified and no new DNA is introduced, is employed in the examples for questions 3–6. However, the technology also makes it possible to add new DNA at a specific site in the genome, such as a gene from the same species (cisgene) or from another species (transgene). In Question 8, we explored the respondents' attitude towards these different approaches.

Question 8. Approaches

Gene editing can be used to modify an animal's own genes in a way that could also occur spontaneously. It can also be used to introduce a new gene variant from a breed of the same species – for example, a gene variant that provides resistance to a virus in chickens. This gene variant could also be introduced through conventional breeding from one breed of chicken to another. The technology also makes it possible to introduce a gene from an entirely different species. Do you consider it right or wrong to use gene editing in each of these different ways? (Multiple answers possible.)

It is right to modify the genes of an animal in a way that could also occur spontaneously.

It is right to introduce a gene variant from a closely related breed.

It is right to introduce a gene from another species.

It is always wrong to modify the genes of an animal using gene technology.

No opinion.

Don't know.

Forty per cent of respondents said it is right to modify an animal's existing DNA. Fewer supported the idea of introducing new DNA from a closely related breed or a different species – 22 per cent and 10 per cent respectively.
More than a quarter, 28 per cent, said it is always wrong to modify an animal's genes, while 11 per cent stated they had no opinion on the matter, and 18 per cent responded "don't know" (Figure 17).
It is clear that acceptance differs depending on the approach used. The highest level of acceptance was found for modifying the animal's own DNA without introducing any new genetic material.

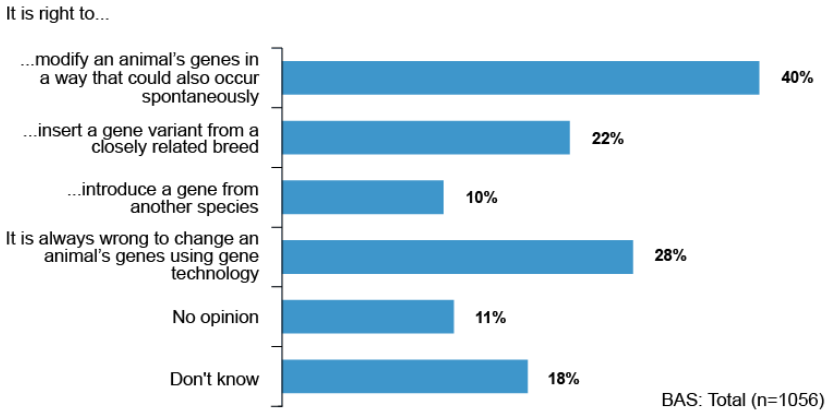


Figure 17. Result of Question 8, animal survey.

2.3.4 No majority in favour of a legislative change for gene-edited animals

The European Commission has tasked the European Food Safety Authority (EFSA) with analysing the risks associated with gene-edited farm animals to human health and the environment. This is a preparatory step ahead of considering whether the EU should develop a legislative proposal similar to the one currently being negotiated for gene-edited plants. Public opinion on such a potential future legislative change is therefore of interest.

Question 9. A theoretical new legislative proposal concerning gene-edited animals

Whether an animal's own genes are modified through gene editing or a gene from another species is introduced, the animal is classified as a genetically modified organism (GMO) under EU legislation. GMOs are subject to very strict legislation within the EU. In practice, this means that the pigs, hens, cows and fish described in the previous questions do not reach the European market.

Outside the EU, some countries are changing their legislation so that a gene-edited animal is not regulated as a GMO, provided that no gene from another species has been introduced.

Do you think it would be right or wrong if the EU were to change the legislation so that gene-edited animals can be bred and products from such animals sold in grocery stores?

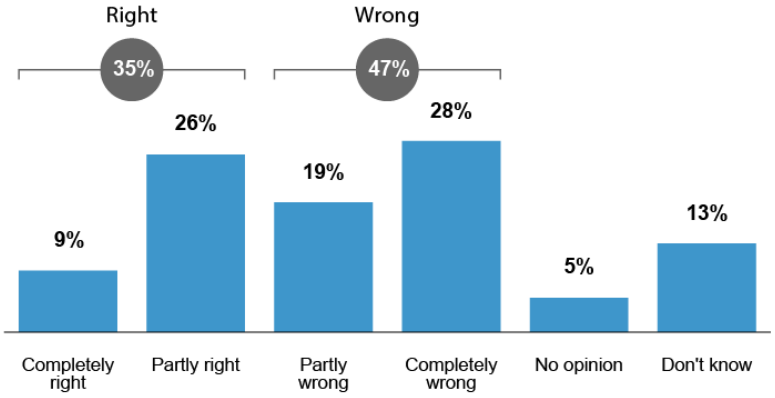


Figure 18. Result of Question 9, animal survey.

More than one third, 35 per cent, answered that it would be right**,** of which 9 per cent answered that it is completely right, if the EU changed its legislation governing gene edited farm animals in the future.

Conversely, almost half of the responders, 47 per cent, considered it wrong, of these 28 per cent answered that it would be completely wrong.

A smaller proportion, 5 per cent, answered that they did not have an opinion on the issue, and 13 per cent said they did not know.

2.4 Who thinks what?

The demographic parameters included in the Novus Sweden Panel provide information about how different demographic groups responded. Additional groups were formed based on the responses to Question 1, concerning self-assessed knowledge of gene editing. This chapter highlights those groups whose responses differ significantly from the overall results (significance level 5 per cent).

2.4.1 Seven out of ten young persons are familiar with gene editing

Prior knowledge was a key parameter influencing participants' attitudes towards the use of gene editing. In an initial question, participants were asked to what extent they were familiar with gene editing, with the following response options: *knew very well*, *knew quite well*, *knew a little*, *had heard of it but hardly knew anything*, and *had never heard of it*. Based on their responses, four groups were formed, each characterised by differences in age, level of education, and whether they lived in a major city or not. Age was the most distinguishing factor for those with prior knowledge about gene editing. In the youngest age group, 18–29 years, 70 per cent had heard of gene editing to some degree. In the other age groups, the share who have heard of it ranged from 45 to 51 per cent.

The group with good knowledge of gene editing

A total of 10 per cent. Those who were more likely to say that they knew gene editing very well or quite well were younger individuals, aged 18–29. In that age group, 28 per cent responded accordingly, compared with 4–8 per cent in the other age groups. This was particularly true for women aged 18–29, among whom 34 per cent stated that they knew gene editing very well or quite well. People in major cities were also slightly more likely to be represented in this group (14 per cent).

The group that knew a little about gene editing

A total of 17 per cent. Those who were more likely to say that they knew a little about gene editing were individuals aged 18–29 (25 per cent) and those with education from college or university (23 per cent).

The group that had heard of gene editing but knew very little

A total of 24 per cent. Those who were more likely to say they had heard of gene editing but knew very little about it were people aged 65–79 (32 per cent) and those with education from college or university (28 per cent).

The group that had never heard of gene editing

A total of 48 per cent. Those who were more likely to say they had never heard of gene editing were people aged 50–64 (55 per cent), and women aged 30–49 (57 per cent). This group also included a higher proportion of people whose highest level of education was primary or secondary school (53 per cent), as well as people living in smaller towns and urban areas or rural areas (52 per cent).

2.4.2 Older people have less knowledge of gene technology

Participants who reported prior knowledge of gene editing were more likely to correctly identify which of the statements in Question 2 were true or false. Those who were unable to distinguish the correct statements, or who answered “don’t know”, were more often individuals who had never heard of gene editing and people aged 65–79.

One statement stood out: that food products based on genetically modified crops are common in Swedish grocery stores. As in the other knowledge questions, people with prior knowledge of gene editing were more likely to answer correctly and identify the statement as false. However, the difference between those with and without prior knowledge was smaller for this statement than for the others. Interestingly, the misconception was most widespread among younger people, aged 18–29 and 30–45, as well as among individuals with education from college or university.

2.4.3 Knowledge influences attitudes

A consistent finding from both surveys was that individuals who reported prior knowledge of gene editing were more positive towards the use of the technology. Those in the group with good knowledge had the most positive attitude. The proportion of positive responses declined step by step down to those who had never heard of gene editing, who were the least positive. This gradient is illustrated in Table 1A.

Table 1A. Self-assessed prior knowledge of gene editing in relation to the responses to Questions 3 and 4 in the plant and animal surveys.

	Good knowledge	**Know a little**	**Have heard of..**	**Have never heard of**
Right to gene-edit potatoes as described in Question 3 (plant survey).	87%	84%	76%	59%
Right to gene-edit tomatoes as described in Question 4 (plant survey).	83%	73%	57%	41%
Right to gene-edit pigs as described in Question 3 (animal survey).	85%	72%	62%	45%
Right to gene-edit cows as described in Question 4 (animal survey).	58%	51%	35%	30%

Previous knowledge of gene editing and age are two parameters that follow a similar pattern. Just as with prior knowledge, the proportion of those with a positive attitude decreases gradually across the age groups. Younger respondents are consistently more positive than older ones. This is illustrated in Table 1B.

Table 1B. Age in relation to the answers to Questions 3 and 4 in the plant and animal surveys

	18–29 years	**30–49 years**	**50–64 years**	**65–79 years**
Right to gene edit potatoes as described in Question 3 (plant survey).	83%	71%	62%	68%
Right to gene edit tomatoes as described in Question 4 (plant survey).	76%	55%	50%	42%
Right to gene edit pigs as described in Question 3 (animal survey).	75%	60%	54%	44%
Right to gene edit cows as described in Question 4 (animal survey).	44%	44%	34%	23%

2.4.4 Men are more positive towards gene-edited crops and animals

Men were more likely than women to respond that it is right to use gene editing on crops and animals in the various examples presented in Questions 3–6. They were also more likely to answer "yes" when asked whether they would consider eating the products from gene-edited crops or animals. The difference between men's and women's responses ranged from 4 to 10 percentage points for the crop-related questions, and from 9 to 25 percentage points for the animal-related ones. For example, 36 per cent of men said they would consider eating the gene-edited fish described in Question 5 of the animal survey, compared with 11 per cent of women. The only cases where women were more positive were when gene editing was used on crops to reduce agriculture's negative impact on the environment and climate, and on animals to improve animal welfare.

2.4.5 Who are the people who believe gene editing is always wrong?

In Questions 7 and 8, respondents could choose the option that gene editing is always wrong when it comes to modifying the genes of a crop or an animal. Among those who answered the plant survey, 11 and 14 per cent (in Questions 7 and 8, respectively) stated that altering a crop's genes is always wrong. Respondents who chose this option were more likely to have never heard of gene editing before, to be men, particularly those aged 50–64, and to live in smaller towns and urban areas or rural areas.

Among those who answered the animal survey, 19 and 28 per cent (in Questions 7 and 8, respectively) said that it is always wrong to modify the genes of an animal. These responses were more common among people who had never heard of gene editing before, and among women, especially those aged 18–29 and 65–79.

2.5 Some changed their opinion following the survey

As the survey included information about a subject that many people either lack knowledge of or know little about – something the Swedish Gene Technology Advisory Board's 2021 survey had already indicated – we examined whether participants had, in any way, changed their opinion after reading through the survey, considering the issues, and answering the questions.

Question 10. Changed opinion

Now that you have answered all the questions, have you in any way changed your opinion regarding the use of gene editing in the development of new crops/or in the breeding of new farm animals?

a) I had a positive attitude, and I am more positive now.
b) I had a positive attitude, but I am more negative now.
c) I had a negative attitude, and I am more negative now.
d) I had a negative attitude, but I am more positive now.
e) I have an unchanged positive attitude.
f) I have an unchanged negative attitude.
g) I have no opinion on the matter.
h) Don't know.

(Those who selected options 1–4, indicating that they had in some way changed their opinion, were also asked which information had influenced that change.)

2.5.1 Nearly one in four more positive to gene-edited crops

Of those who answered the plant survey, a total of 23 per cent stated that they had changed their opinion and become more positive. Most of those who changed their mind in this way, 18 per cent, said they had previously held a negative opinion but had become more positive. This change was more common among women aged 30–49 and 50–65, (26 and 24 per cent respectively). A smaller share, 5 per cent, said that they were already positive but had become even more positive after participating in the survey.

A small share, 5 per cent, changed their mind in the opposite direction, of which 2 per cent had gone from being positive to negative, and 3 per cent were already negative and had become even more negative.

One in four, 25 per cent, said that they remained positive. This was more common among those who knew gene editing very well or quite well from before (56 per cent), younger people aged 18–29 (43 per cent), men (31 per cent), and those with education from college or university (30 per cent).

Somewhat fewer, 20 per cent, remained negative. Women aged 65–79 (28 per cent) and men aged 50–64 (26 per cent) were overrepresented in this group (Figure 19).

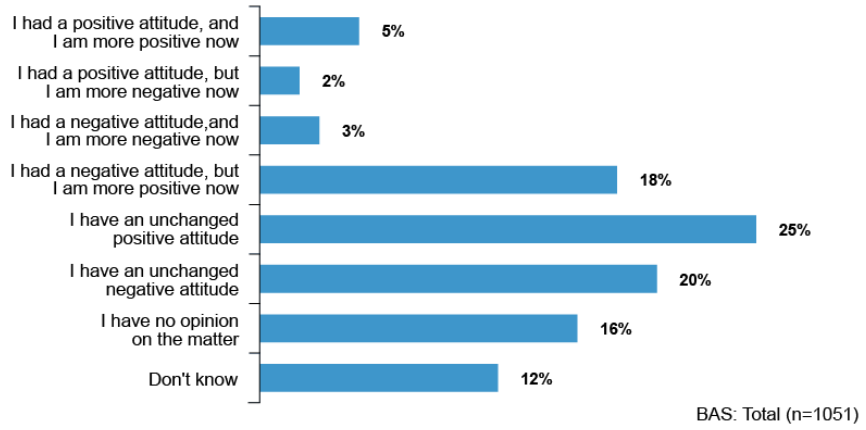


Figure 19. Responses to Question 10 in the plant survey.

2.5.2 Fewer changed their opinion about gene-edited animals

Of those who answered the animal survey, a total of 12 per cent said they had changed their opinion and become more positive towards gene-edited animals after participating in the survey. Of these, 10 per cent had gone from a negative to a positive view. This shift was more common among those who had heard of but hardly know of gene editing (16 per cent), women aged 30–49 (15 per cent), and those with education from college or university (14 per cent). A tiny share, 2 per cent, said they had been positive to begin with and had become even more positive.

In total, 9 per cent said they had become more negative. Of these, 3 per cent had gone from positive to negative, which was more common among women aged 18–29 (9 per cent). Those who had already held a negative view and had become even more negative made up 6 per cent, and this was more common among women aged 65–79 (13 per cent).

One fifth, 20 per cent, said they remained positive. This was more common among those with a good knowledge of gene editing (55 per cent) and those who stated they knew a little about it (29 per cent), younger people aged 18–29 (33 per cent), men (28 per cent), particularly men aged 18–29 (46 per cent) and 30–49 (29 per cent).

One third, 32 per cent, remained negative. This group included a higher share of people aged 50–64 (37 per cent) and those who live outside major cities (see Figure 20).

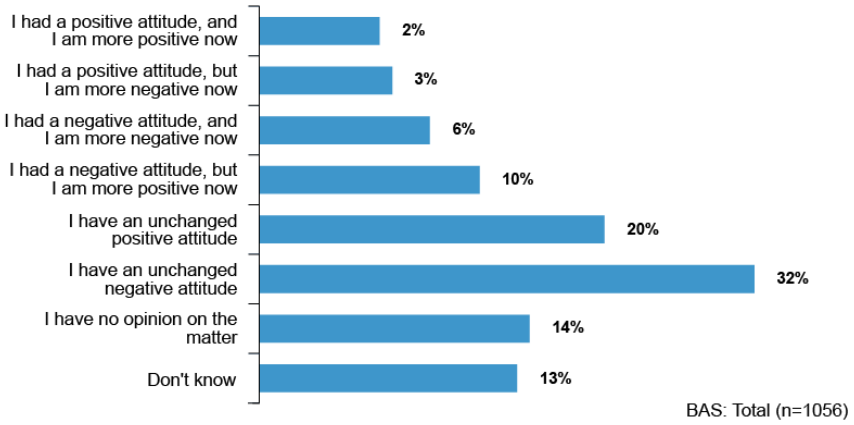


Figure 20. Responses to Question 10 in the animal survey.

2.5.3 Factors contributing to a change in opinion

Those who indicated that they had changed their opinion were also asked whether any specific information had influenced their shift in view. Participants could respond in their own words.

The most frequently mentioned reason for developing a more positive view of gene edited crops was being presented with the potential societal benefits that the technology could bring. Other commonly cited reasons included having "gained more knowledge." Some participants highlighted the information that gene editing does not require the addition of a new gene to the crop as important for their more positive attitude.

Those who had changed their opinion and become more negative towards gene-edited crops also often cited "increased knowledge" as a contributing factor, and the opportunity for reflection. Their written responses expressed some surprise that the use of the technology had "come this far," that other countries already approve gene-edited crops, and that EU legislation may be about to change.

In this group, terms such as “unnatural” and “uncertain” were often used to describe why they had become more negative.

The most common reason given for developing a more positive attitude towards gene edited animals was also “increased knowledge.” Many participants who had become more negative expressed disbelief in their written responses, such as, “things had already gone this far” and that they “did not know this is being done to animals.” More emotionally charged words such as “frightening,” “scary,” “unethical,” and “horrible” were used in the responses from those who had developed a more negative attitude.

3 Reflections

The rapid pace of technological development, and potential regulatory changes within the EU, makes it likely that gene-edited foods will become a reality in Sweden. In this study, we have analysed the Swedish public's level of knowledge and attitudes towards gene editing in the agricultural sector, including gene-edited crops and farmed animals.

3.1 Limited knowledge of gene technology among the public

Based on previous surveys, we suspected that knowledge of gene editing was relatively low. Therefore, we wanted to present concrete examples from ongoing research and development - both to inform the respondents and to analyse whether the different overarching purposes given in the examples influenced attitudes toward the products. In the examples, it was explained that apart from the induced genetic modification, the crop or animal was no different from its original version. We also briefly explained how gene editing works and that it, in most cases, only involves modifying existing DNA. This setup enabled us to analyse whether respondents' attitudes had changed by the end of the survey, given the brief information they had been exposed to.

The survey results indicate that Swedish public's knowledge of genetics and gene technology is limited. A relatively large proportion answered "Don't know" to the knowledge questions, and participants tended to say they believed rather than knew the correct answer. Nearly half said that they had never heard of gene editing, CRISPR/Cas or gene scissors. The other half had, to varying degrees, heard of gene editing. When we asked the same question in the attitude survey from 2021, the result was almost identical.

The lack of knowledge about gene editing, especially among older individuals, may partly be explained by younger people having learned about the topic in school. However, even for younger people, more in-depth education has generally been limited to upper secondary school science programmes. The concept of gene editing was not widely discussed in society until CRISPR/Cas9 was described in a scientific article in 2012, and its use began to spread. Over the past few years, CRISPR/Cas9 has gained attention in the media, especially when Emmanuelle Charpentier and Jennifer Doudna, who developed the CRISPR technique, were awarded the Nobel Prize in Chemistry in 2020.

3.2 Prior knowledge and attitude

The results revealed a consistent pattern: individuals who had never heard of gene editing were more negative toward the technique being used—both on plants and animals.

A model that has been important in explaining how people react to gene technology (and other new technologies) in the food sector is the ‘affect heuristic’. This model describes how, in situations of uncertainty—such as a lack of knowledge or when the question is complex—people create a mental shortcut and let immediate feelings and associations guide them to a conclusion, often leading to a negative attitude.[12–15]

Social trust can also create a similar mental shortcut.[15–17] How the use of technology is regulated and communicated in different countries can send a signal to citizens and influence whether a particular technology is perceived as risky or not. Trust in the institutions in society that use gene technology also impacts the acceptance of the technology and its perceived safety.[18] In the survey's free-text answers, we sense trust in the information from the Swedish Gene Technology Advisory Board, as a relatively high number of respondents mentioned a shift towards a more positive attitude, based on the information they received in the survey. Previous studies have shown a high level of trust in both food systems and public authorities in Sweden.

3.3 The ideal of naturalness

Another factor that frequently arises when researchers seek to understand the public’s attitude towards gene technology in the food sector is the perception of what is considered “natural”.

In the survey, people with a negative view described altered plants and animals as "unnatural," and expressed negative feelings about them. The word "natural" tends to evoke a positive reaction in almost all people in the Western world, with food perceived as natural being assumed to be healthier, tastier, and better for the environment. Domesticated crops and animals that have not been modified using gene technology are viewed as more natural than their modified counterparts, and the modification itself can be perceived not only as unnatural but as a violation of nature, and thus morally wrong.[19–22]

The perception of naturalness reappears as an explanatory model in scientific literature, since even when a person views gene technology as safe and beneficial, it does not automatically lead to acceptance. The feeling that the food one eats is unnatural and morally questionable can outweigh information about risks and benefits, especially when the benefits are not perceived as immediately significant.[22]

3.4 More ethical concerns regarding gene-edited animals than crops

When comparing the results from the plant and the animal survey, a consistently more positive attitude towards gene editing in crops compared to animals becomes evident.

A larger proportion of respondents stated that it was right to use gene editing to develop crops in Questions 3–6 of the plant survey, compared with the examples presented in the animal survey. Twice as many answered that it is always wrong to gene edit animals compared with gene editing crops.

This difference in attitudes was also reflected in how participants responded to the question of whether EU legislation should be amended to allow gene-edited crops to reach the market. Half of the respondents thought it would be entirely or partly right in the case of crops, whereas the corresponding figure for animals was 35 per cent. Similar differences in attitudes toward gene-edited plants and animals have been reported in several other studies.[10,11]

In the animal survey, free-text responses more frequently included comments on ethical aspects of gene editing, such as, "animals are sentient beings that we must treat with respect." Questions like "Why must humans always benefit from everything?" and "Who are we to decide over their [the animals'] lives, take their offspring and modify their genes?" were common. Many also stressed that animal welfare and rights must come first.

Among those who responded to the plant survey, concerns primarily focused on the potential negative impact of gene-edited crops on biodiversity, health, and the environment, as well as on the risk that large corporations could outcompete small-scale farmers. Participants of the plant survey did not raise explicit ethical considerations to the same extent as participants if the animal survey.

3.5 Modifying existing DNA is more accepted

There was greater acceptance of modifying existing DNA – which is the most common approach in gene editing – compared with introducing new DNA (cisgenic or transgenic modification). Attitudes also differed depending on whether the introduced DNA came from the same or a closely related species (cisgenesis), – or from a different species (transgenesis). Cisgenic modification was, in this comparison, more accepted. Similar results have also been observed in other studies, where gene editing has been perceived as less invasive, safer and less "unnatural."[7–9,23–25]

The importance of modifying existing DNA, rather than introducing new DNA, was also highlighted when respondents who had changed their view from negative to more positive regarding gene editing of crops were asked to elaborate on their reasoning. In their free-text responses, "usefulness" was the most frequently mentioned reason, but the second most common was "the information that existing DNA is modified."

3.6 The purpose of gene editing matters for acceptance

The survey indicates that a majority of the Swedish public holds a positive view of using gene editing in crop breeding if the purpose is to benefit society, such as reducing the use of pesticides. When the examples did not present a socially beneficial purpose, acceptance dropped, as in the example of the purple carrot. A similar result was observed in the 2021 survey. Nearly three out of four (73 per cent) were very or somewhat positive in 2021 towards gene editing potatoes to make them less dependent on pesticide treatment. Only one in ten were positive about modifying the shape and colour of fruits and vegetables.

There was some acceptance of gene editing in animals as well – but only if the aim was to improve animal welfare. The only purpose that a majority supported was improving the welfare of animals (Question 7). The gene-edited virus-resistant pig (Question 3), which many likely interpreted as a welfare improvement, was the example with the highest level of acceptance. In general, however, most of the Swedish public was not in favour of using gene editing on animals, nor of changing EU legislation to allow products from gene-edited animals to reach the market.

In conclusion

Our survey revealed that the Swedish public holds a distinctly positive attitude towards gene-edited crops, particularly when the purpose is clearly beneficial to society. This aligns with previous studies, which have shown that the population in the Nordic countries tends to have a generally positive stance towards genetically modified crops. However, attitudes towards gene-edited animals are more ambivalent, with ethical concerns emerging as key factors influencing acceptance. The survey also suggests that there is support among the Swedish public for easing regulations on gene-edited crops.

4 How the study was conducted

Two web-based surveys were conducted from 29 August to 11 September 2024 in collaboration with the analysis firm Novus. The surveys were designed by Mia Olsson and Annelie Carlsbecker at the Swedish Gene Technology Advisory Board's office, in consultation with Novus and members of the Board. One of the surveys focused on the Swedish public's attitude towards gene-edited crops (plant survey), and the other on gene-edited farm animals including farmed fish (animal survey).

4.1 A representation of opinions in Sweden

The plant and animal surveys received responses from 1,051 and 1,056 individuals respectively, drawn from Novus' randomly recruited Sweden panel, which provides a representative sample of people registered as living in Sweden, considering factors such as gender, age, and home region. The age range of respondents was between 18 and 79 years. The response rate was 53 per cent. Any potential skewness in the structure of the panel was addressed by selecting a nationally representative sample from the panel and weighting the results accordingly.

The panel includes demographic data relating to gender, age, education level, occupation, household income, housing, home region, and whether there are children in the household (see Table 3). When significant differences are discussed, it means that a demographic group has responded in a way that differs markedly from the overall sample to an extent that cannot be attributed to random variation (significance value of 5 per cent). In addition to groups based on demographic parameters, a further group was created based on how respondents answered the first question in the survey, which assessed their self-estimated knowledge of gene editing.

Table 3. Demographic parameters linked to the panel

Parameter	Response alternatives
Gender	Female Male
Age (years)	18–29 30–40 50–64 65–79
Highest completed education	Primary school or equivalent Secondary school or equivalent Collage/ university
Occupation	White-collar employees Blue-collar employees Retirees
Marital status	Married/partnership Common law partner Other
Annual household income (SEK)	0–299 000 300 000–499 000 500 000–799 000 Above 800 000
Children living in household	Yes No
Home address	Major cities (further sub-divided into Stockholm, Gothenburg, and Malmö) Smaller towns and urban areas Rural areas
Home region	Stockholm Eastern Southern Western Northern
Major city region	Major cities Smaller towns and urban areas/rural areas
Self-estimated knowledge of gene editing (based on responses in Question 1)	Know very well Know quite well Know a little Have heard of but hardly know anything Have never heard of

4.2 Design of the surveys

The first two questions in the survey were identical and designed to assess the respondents' current knowledge. The first question asked about their self-assessed knowledge of gene editing. Question 2 presented four statements about genetics and gene technology, and the respondents were asked to indicate whether they believed the claims to be correct or incorrect. The knowledge questions were followed by a short information text about gene editing, shown in Fact Box 1 and 2. The report presents the answers to Questions 1 and 2 from both the plant and animal surveys together, as the results were very similar.

After the knowledge questions, additional questions were asked to investigate the respondents' attitudes towards the use of gene editing in plant breeding or the breeding of farm animals. The first four questions about attitudes (Questions 3–6) were divided into two (A and B), beginning with briefly describing an example of a crop or animal modified using gene editing. The first question in each pair asked whether the respondent thought it was "right or wrong" to use gene editing in the way described in the example (affective component), followed by the question "Would you consider eating X?", where X referred to the crop or the meat, milk, or eggs from the animal in the example. This latter question was aimed to assess the respondents' preparedness for action in response to the attitude object (intentional component).

Further questions about the respondents' attitudes were asked, designed to investigate whether the purpose of the gene editing was important (Question 7), whether the way gene editing was used was significant (Question 8), and, finally, a question about the respondents' views on changing EU legislation concerning gene-edited crops or animals (Question 9). To conclude the survey, respondents were asked whether they had changed their minds and become more positive or negative towards gene-edited crops or animals (Question 10). If they indicated that they had changed their minds, they were asked whether any specific information had influenced this change. All respondents had the opportunity to provide comments before completing the survey.

5 Introduction to breeding, gene technology, and legislation

5.1 Breeding, mutations, and gene technology

For thousands of years, humans have intentionally, or sometimes unconsciously, altered the traits of the plants we cultivate and the animals we keep. New or altered traits can arise through mutations, which occur spontaneously in each generation of all organisms. Typically, new mutations go unnoticed, without affecting the organism's traits. However, occasionally, a mutation will result in a noticeable change. In the domestication process, where wild plants and animals evolve into crops and livestock, the mutations and traits that have been beneficial to humans have increased in frequency over time. The genetic variation that arises through mutations is the foundation for both domestication and evolution.

In recent centuries, we have increasingly focused on intentionally changing the traits of crops and animals, employing more advanced methods. This process is often described as breeding. These breeding techniques have evolved through several stages of innovation, from natural selection and crossbreeding, to random mutagenesis using radiation or chemicals (in the case of plants), and to genetic modification, where new genes are transferred - referred to as 'transgenesis'. In the past decade, significant advancements have been made in the use of targeted mutagenesis through gene editing . Both random and targeted mutagenesis involve inducing mutations and actively increasing genetic variation, which can lead to the emergence of new traits.

Random mutagenesis

To increase the number of new mutations that could lead to desirable traits in plant breeding, researchers in the 1930s and 1940s began using radiation or mutagenic substances to treat seeds. This process resulted in thousands of new mutations that were randomly distributed across the plant's genome. Plants that exhibited favourable traits were then selected for further breeding. This method, known as random mutagenesis or mutation breeding, is still used today in plant breeding. Since the 1930s, thousands of plant varieties have been developed using mutation breeding techniques. Plants subjected to random mutagenesis are, by definition, genetically modified organisms (GMOs); however, they are excluded from regulation under the EU's GMO legislation, meaning there is no requirement for risk assessment for these plants.

Transgenesis

In the 1980s, researchers discovered how to introduce new DNA into the cells of animals and plants, changing their traits. An organism that receives a gene from another organism is called transgenic. If the gene comes from an organism that could naturally crossbreed with it, it's sometimes referred to as cisgenesis. Whether cisgenesis or transgenesis, the organism is still classified as a GMO.

Genetically modified crops are cultivated in nearly 30 countries, spanning 200 million hectares. These crops are most prevalent in North- and South America. The primary crops include soya beans, maize, and oilseed rape, which have been modified for herbicide tolerance and insect resistance, primarily for use as animal feed and human food. Insect-resistant cotton is also grown across vast areas in other parts of the world, though a range of other genetically modified crops are cultivated on a smaller scale. The EU has very restrictive legislation, with a high threshold for commercial approval. Within the EU, only one variety of maize for animal feed is grown in Spain and, to a lesser extent in Portugal. However, the EU imports around 30 million tonnes of genetically modified maize and soya beans for use in animal feed, along with a few other products.

When it comes to breeding farm animals, transgenic genetic modification has been used sparingly. However, fast-growing salmon and pigs that lacks the alpha-gal allergen are available on the North American market.

Targeted mutagenesis with gene editing

In the 1990s, gene-editing techniques were developed to alter existing DNA at a specific location within a gene. These techniques are based on an enzyme that cuts a specific, unique DNA sequence. A mutation occurs when the cell repairs the damage caused by the enzyme. This method of inducing a mutation at an exact and pre-determined site is also known as targeted mutagenesis. The first gene-editing techniques developed were zinc finger nucleases (ZFN), mega nucleases, and TALENs (transcription activator-like effector nucleases). The enzymes that cut the DNA are sometimes called 'genetic scissors'.

The use of gene editing accelerated after 2012 with the development of the CRISPR/Cas9 technique (CRISPR stands for clustered regularly interspaced short palindromic repeats). Unlike earlier gene-editing techniques, CRISPR/Cas9 uses a target-seeking molecule along with the enzyme that cuts the DNA. The target-seeking molecule is a guide RNA, and the enzyme is Cas9. CRISPR/Cas9 has become dominant among gene-editing tools because the guide RNA can be quickly and easily reprogrammed and directed at a new location in the genome, such as a gene. This makes CRISPR/Cas9 a more flexible and user-friendly tool than the techniques developed in the 1990s.

Currently, a few gene-edited crop and animal products have been approved for various non-European markets, but significant research is ongoing particularly to develop crops with new traits.

5.2 Legislation governing gene editing

The EU's GMO legislation regulates all use of gene editing in plant and animal breeding. Directive 2001/18/EU on the deliberate release of GMOs into the environment describes the techniques that lead to a regulated GMO and those that do not. Gene technology has developed rapidly over the past 30 years. Still, the descriptions and definitions in the legislation remain the same as those in the GMO legislation that came into force in the 1990s.

Random (but not targeted) mutagenesis is exempt from legislation

In the context of plant breeding, random mutagenesis is excluded from GMO legislation, because these techniques have a history of safe use. However, organisms improved using new genomic techniques (NGTs), such as gene editing, are not exempted. NGTs are defined as techniques that have emerged since 2001, when EU Directive 2001/18/EU was adopted. In practice, this means that thousands of random mutations may be introduced into a plant during the breeding process without the need for a risk assessment regarding potential health or environmental concerns. However, a plant that has received a targeted mutation, such as one generated using CRISPR/Cas9, must undergo a risk assessment.

Difficult to implement GMO legislation on certain NGTs

Before a crop or an animal that has been genetically modified, either through transgenic techniques or gene editing, can be approved for import or for cultivation or breeding within the EU, it must be assessed on a case-by-case basis and compared with its non-modified counterpart to determine whether there are any health or environmental risks associated with the GMO. The applicant must submit extensive documentation. There are also far-reaching requirements for traceability and labelling.

The traceability requirement makes the legislation difficult to implement for gene-edited organisms. To trace a GMO, the applicant must provide technical solutions that allow laboratories to detect the modification. This requirement creates difficulties in the case of gene editing, since a mutation induced by gene editing cannot be distinguished from one that has occurred spontaneously or through random mutagenesis.[26] Developing robust detection methods for identifying a known mutation at a reasonable cost is also technically challenging. As a result, it is difficult or even impossible to gain approval for a gene-edited organism within the EU.

The process for obtaining marketing authorisation is also lengthy and costly, making it inaccessible to small and medium-sized companies. Within the EU, only one genetically modified crop, a feed maize, is currently approved for cultivation (see section describing transgenesis).

An application to place a food product from a gene-edited farm animal on the market in the EU would be evaluated in the same way under the GMO legislation, but to date, no such application has been submitted - neither for a transgenic farm animal nor for a gene-edited farm animal.

New legislative proposal on NGT-bred plants (but not animals)

In a study published by the European Commission in 2021, it was concluded that the current GMO legislation is not fit for purpose when it comes to gene-edited crops, known as NGT-bred plants. One reason is that the requirement for detection and traceability cannot be met. The current legislation has also been criticised for hindering European research and innovation and for making trade more difficult with countries that, in various ways, exempt gene-edited organisms from regulation under their national GMO legislation. More than 30 countries have eased their regulations in this way and exclude NGT-bred crops (and in some cases animals) from their respective GMO legislation, including the United States, Japan, the United Kingdom, and several countries in Latin America.

Within the EU, the European Commission presented a legislative proposal in the summer of 2023 that would exempt certain NGT-bred plants (but not animals) from the EU's GMO legislation. The criterion is whether the plant has undergone genetic modifications that could have occurred spontaneously or through techniques used in conventional breeding. The proposal is currently being negotiated and has not yet been approved. The European Commission has also tasked the European Food Safety Authority (EFSA) with assessing potential risks to health and the environment from animals modified with NGTs for use as food.

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