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A rapid evidence assessment of consumer views on emerging food technologies

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Collingwood Environmental Planning

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Executive summary

Context and scope

The development of new and emerging food technologies and their applications is a fast growing area. The Food Standard Agency's (FSA) focus on protecting consumer interests in relation to food, means it needs to understand and keep up to date with consumers' views towards these technologies.

This report presents the results of a rapid evidence assessment (REA) conducted by Collingwood Environmental Planning (CEP) to update the FSA's existing evidence base (see FSA, 2009). The technologies covered are genetically modified (GM) foods, nanotechnology applied to foods, functional foods, cultured meat, novel food (in the UK) such as insect foods, food from a cloned animal, 3D printed foods, and synthetic biology applied to food.

Overall findings

What are the public's views on emerging food technologies?

Key themes within public/consumer views on emerging food technologies relate to perceived risks and benefits of the technology, including:

- A perceived unnaturalness, where in extreme cases perceived unnaturalness can evoke a disgust factor.
- Ethical concerns, particularly in agri-food applications of certain technologies.
- Ambivalence as both hopes and concerns are often expressed.

How do views differ depending on the type of technology?

- Attitudes toward a food technology can vary depending on the type of application and the context.
- Attitudes are similar between some of the technologies.
- Some technologies tend to evoke mostly positive attitudes, whereas others negative attitudes or low acceptance.

What shapes the public's views?

Key factors that shape views include:

- Contextual factors (for example, previous societal experience).
- Risk perceptions (for example, naturalness and controllability of effects).
- Perceptions of benefits.
- Food governance: how the food is regulated, who benefits, and trust in the institutions developing the technologies.
- Individual characteristics such as knowledge/information.

- Framing of information can affect attitudes towards technologies (for example cultured meat, synthetic biology).

Do different types of people hold different views?

There is some limited evidence that consumers' attitudes can vary in terms of the following factors, however findings cannot be generalised given the small number of studies and the mixed findings:

- Gender: men tend to be more accepting/positive towards cultured meat, food from a cloned animal, nanotechnology, GM food, synthetic biology and 3D printed food.
- Age: younger people have been found to be more accepting of insect eating, cultured meat and food from a cloned animal but age has not been found to influence acceptance of 3D printed food or synthetic biology. Older people are more likely to buy functional foods.
- Education: higher level of education is linked to positive attitudes towards cultured meat, GM foods and food from a cloned animal, synthetic biology and nanotechnology.
- Household structure was found to be related to consumer views: for example, acceptance of functional foods increased with the presence of children in the household whereas the presence of children under 12 years made adults less accepting of food from cloned animals.

How do views affect behaviour such as food choices?

- Perceptions of health benefits and positive attitudes were linked to intentions to buy functional foods.
- Consumers were less likely to indicate an intention to buy once they knew the product was food from a cloned animal, and cultured meat. Views on the environment and animal ethics were related to these decisions.
- Price has an effect, with people more willing to buy GM foods if available at a reasonable price.
- Having a 'green' healthy lifestyle is linked to willingness to eat insects.
- Consumer preference for labelling of nanotechnology food applications is positively linked to their willingness to buy, but this is not the case for GM foods.
- Little evidence of consumer willingness to incorporate 3D printed food into everyday food choices.

How have views changed since 2009?

- For some technologies, there is some evidence that consumers' attitudes have not changed (functional food) and largely remaining negative (GM foods, synthetic biology, food from a cloned animal).
- For other technologies there is some evidence that views have changed from positive to ambivalence or even reluctance since 2009 (nanotechnology).

- For some technologies, there is some evidence that attitudes are now more formed (food from a cloned animal) or more nuanced and context dependent (food applications of synthetic biology) than in 2009. The reason for this is unclear.

What are the gaps in current research?

- Research is needed for most of the food technologies on views towards specific food applications, as opposed to the technologies per se, and the influence of a wider range of factors that may influence consumer attitudes, such as, product characteristics, geographic and cultural regions, socio-demographic factors, media and different types of information.
- Longitudinal studies are lacking for several technologies.
- There is a need to better understand consumer decision making in relation to how people make trade-offs between risk and benefit perceptions.

Key findings by technology

Genetically modified foods

- Concerns related to GM foods include: ‘unnaturalness’, unknown risks, lack of perceived benefits, potential ‘unavoidability’ of risks, health implications, the motivations of those promoting the technology and a sense of fatalism over the expansion of GM food.
- Factors that influence the public’s perceptions of GM foods include trust, scepticism, knowledge, information, media, education, age, and living environment/culture. Attitudes are more negative towards animal based GM foods than plant based GM foods.
- Price seems to play a key role when it comes to purchasing decisions.
- Views are largely similar to those presented in 2009.

Nanotechnology applied to foods

- Consumer awareness and understanding of nanotechnologies applied to food is relatively low.
- No consensus exists among the reviewed literature about what the publics’ views are on nanotechnology in food.
- Attitudes towards nanotechnology in food are generally more positive than attitudes towards GM food.
- Views have changed since 2009 from positive to ambivalence and even reluctance.

Functional food

- Consumer attitudes towards specific functional food products depend on the perceived necessity of the product, perceived healthiness, and the perceived

naturalness of the combination of 'carrier' product and added functional ingredient.
- Overall no evidence to suggest that views have changed since 2009.

Cultured meat

- Survey data in the UK indicates that 16% – 19% of consumers would eat cultured meat, 42% - 62% would not, and 19% - 40% are undecided.
- The most pressing concerns about cultured meat for consumers are around food safety and health impacts.

Novel food processes – insects as food

- Familiarity with and acceptance of eating insects is growing rapidly.
- Health conscious, environmentally aware people are more likely to consume foods produced with insect proteins.
- Media attention is acting to increase awareness and promote sector growth.

Food from a cloned animal

- Most consumers are critical towards this technology mainly due to food safety, ethical, animal welfare, absence of labelling, economic and environmental concerns.
- Higher acceptance of food from a cloned animal is seen amongst men, left-leaning individuals, urban consumer, primary grocery shoppers and families with older children.
- Since 2009, attitudes remain unsupportive, though appear to be more formed.

3D printed food

- Consumers tend in general to have low levels of knowledge and familiarity, and negative attitudes towards 3D printed food technology.
- Views towards 3D printed food are influenced by appearance, perceived safety, extent of processing, healthiness/nutrition and tastiness, knowledge and information, perceived 'fun to use', fear of eating new or alien food and of the use of novel technology in food production.
- Informing consumers about 3D printed food technology can impact attitudes.
- Relevant aspects of 3D printed food technology to promote include 'fun to use', convenience, health and personalised nutrition. Consideration should also be given to food content, the sensory qualities, level of processing.

Synthetic biology applied to foods

- There is no clear consensus in the reviewed literature on consumer views towards synthetic biology in food.
- Consumer attitudes are generally more positive towards applications with clear benefits for example medical, energy and environment applications rather than for food

- Attitudes toward synthetic biology are similar to those to GM food with concerns around 'unnaturalness' and 'playing God'. On the other hand, consumers express a sense of hope that synthetic biology could address issues such as food security. This suggests ambivalence about the technology.
- Since 2009 there have been papers on specific applications of synthetic biology in food and as predicted views do have some similarities to attitudes towards GM foods. However, there is still a need for longitudinal studies and more systematic studies on specific food applications of synthetic biology.

Conclusions and future research

Across all the technologies examined no single picture emerges of consumer views. This is partly because of the inherent variability of the different technologies and the issues their development is aiming to address, and partly because of the lack of systematic studies on consumer views especially in relation to specific applications of the technologies. These conclusions should be read with those caveats in mind. However, there are a number of themes that can be drawn out across the technologies: naturalness/unnaturalness, controllability/uncontrollability and the possibility of unforeseen consequences, benefits/risks/attitudinal ambivalence, knowledge, and perceptions of the efficacy of governance of, and trust in the food system. Demographic factors such as gender, age, etc. appear to have less clear effect on attitudes and behavioural intentions than perceptions of risks and benefits.

Future research

In terms of areas for future research the following are suggested:

- Comparative research into different food applications of the technologies and changes in consumer views of them over time (for example, risk perceptions, benefit perceptions, perceptions of unnaturalness, etc.) to assess both relative levels of acceptance/rejection and the factors contributing to this. Research to understand how perceptions of benefits and risks associated with the technologies are changed through exposure to different types of information and how these perceptions are maintained or change in the long-term following the intervention.
- Research on purchasing and/or eating behaviours in relation to foods produced using emerging food technologies that come onto the market, in order to make sense of actual (rather than hypothetical) behaviours.
- Longitudinal research on consumer views across most of these areas to understand change over time and the impact of familiarity/context.
- Research into the relationships between the technologies to understand how new technologies with similar characteristics might be viewed in the future, for example by using techniques like future scenarios.

Introduction

The development of emerging food technologies and their applications is a fast growing area of science and technology. Innovations over the past decade range from the development of cultured meat[1], grown without harming animals, through to the use of synthetic biology techniques (for example, producing shrimps from algae) and 'printing' food using 3D technologies. Unsurprisingly, the media tend to focus on the more dramatic aspects of some of these technologies.

Would you eat HUMAN meat grown in a lab? Controversial scientist Richard Dawkins suggests it could 'eradicate the taboo against cannibalism'

Mail Online, July 2019

Millennials 'have no qualms about GM crops' unlike older generation

The Telegraph (online), May 2018

However, it is vital to go beyond the headlines to understand how consumers view these technologies: their hopes and concerns about these technologies and specific applications, in order to have a more nuanced picture of under what conditions they might be accepted or rejected.

The FSA commissioned CEP to carry out a Rapid Evidence Assessment (REA) on emerging food technologies, with a view to updating its evidence base in this area building on the work carried out in 2009 (FSA, 2009). This report presents the findings from the REA and expert interviews.

The overall research question addressed in this report is: **What are consumers' views of emerging food technologies, how have these changed over the last decade and what insights might we glean from this to inform future policy?**

To answer this question there are eight sub-research questions:

1 Cultured meat is also sometimes referred to as 'lab-grown meat' or 'in vitro meat'.

- SRQ1 What are the public's views on emerging food technologies?
- SRQ2 How do views differ depending on the type of technology?
- SRQ3 What shapes the public's views?
- SRQ4 Do different types of people hold different views?
- SRQ5 How do views affect behaviour such as food choices?
- SRQ6 How have views changed over time?
- SRQ7 What are the gaps in current research?

This report briefly describes the methodology used for the REA and interviews, presents the main findings for each research question followed by more detailed reviews for each technology, before providing some overall conclusions.

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Methodology

REA protocol

The REA protocol (see Annex) describes how the REA was carried out, focussing on the inclusion/exclusion criteria, search string, sources of evidence and approach to prioritisation of documents. As far as possible we aimed to use the same approach to that used in 2009. We have highlighted where there are differences and provided a rationale for any changes. The protocol follows the structure laid out in the Defra/NERC guidance on the production of quick scoping reviews and rapid evidence assessments (Collins et al., 2015).

Overview of literature

Following the methodology set out in the REA protocol (see Annex), a final list of 115 articles was produced to be used in this review. This included literature resulting from a search in Scopus, grey literature, and any further additional literature as suggested by our expert interviewees that fulfilled the exclusion criteria. The number of articles per emerging food technology varied, reflecting the extent of literature coverage for each. Prioritisation criteria were applied to the lists of literature for each technology and the articles most relevant to the research questions were used in the final analysis. For some of the emerging food technologies more literature was deemed relevant than was ultimately possible to include in this review – in these cases, the literature considered most relevant were selected (see Annex for details of prioritisation criteria). Of the final list of literature, 93 documents were reviewed in detail and are included in the findings of this report, as summarised in

Table 1 (see Annex for the total number of papers identified at each stage of the review process and the number included in the final review for each technology).

Table 1. Summary of final literature reviewed for each technology

Technology	Total no. of papers included in review	No. of review papers	No. of empirical papers	No. of other
Cultured meat	23	9	14	0
Food from a cloned animal	9	3	5	Position paper = 1
Functional food	11	3	8	0
GM food	11	3	5	Mixed review and empirical = 3
Nanotechnology	10	5	5	0
Novel food processes	17	4	9	Book chapters = 3 Opinion paper = 1
Synthetic biology	6	3	2	Public dialogue process = 1
3D printed foods	6	0	5	Conference paper = 1
Total included	**93**	**30**	**53**	**10**

Limitations

- The reviewed literature was described according to their robustness across a number of factors as part of the analysis and synthesis process[2]. However, this was not formally analysed and presented as part of the findings and is a limitation as it reduces transparency of the REA process. Rather, it fed into the expert judgement of team members as to whether or not a paper was of sufficient quality to be part of the review. Given that the majority of papers were from peer reviewed journals we are confident of a general level of scholarship for these papers reviewed. For the grey literature where a number of those criteria did not apply, experts used their judgement and generally grey literature was from known and reputable sources or recommended by our expert interviews.
- Using some of the search terms as complete words rather than with * could be considered a limitation. Scopus does automatically search for plurals as well as popular differences in spelling US/UK. The term ‘citizen’ was not included in

[2] Each source was described in relation to: whether or not it was peer reviewed, number of citations, journal impact factor, quality/robustness of the conclusions for example, were they backed by good data/findings, and whether or not limitations of data and quality were discussed.

the original search string and could be considered an omission. Trialling the search string with it in together with accept* and percept* returned only three extra papers in the case of lab-grown meat. We would suggest that these changes are made for further work in this area for completeness but are content that the approach taken, combining expert and e-searches, has resulted in comprehensive coverage of papers.

Overall findings

What are the public's views on emerging food technologies?

- Key themes within public/consumer views on emerging food technologies relate to perceived risks and benefits of the technology.
- a perceived unnaturalness, which in extreme cases can evoke a disgust factor.
- ethical concerns, particularly in agri-food applications of certain technologies.
- ambivalence as both hopes and concerns are often expressed.

Public attitudes towards certain emerging food technologies are generally negative when there is a high level of perceived unnaturalness, ethical concerns, and low ratio of perceived personal benefits versus risks. From the evidence reviewed this is shown to be the case for GM foods and food from cloned animals. However, it appears that where the perceived benefits of a technology outweigh the perceived risks the public attitudes tend to be somewhat positive, as in the case of nanotechnology in food.

Public attitudes towards GM foods have been extensively studied and, in Europe, appear to be increasingly negative. Although there are several perceived benefits of GM foods including extended shelf-life, resistance to disease, bacteria, viruses, pests and extreme climatic conditions, higher yield/less resource intensive yield, and reduced need for artificial fertiliser; key issues relate to the perceived 'unnaturalness' of GM foods, unknown risks, lack of perceived benefits, 'unavoidability', potential health implications, and the motivations of those promoting the technology (Grove-White et al., 1997; Nelson, 2001; Shaw, 2002; Pidgeon et al., 2005; Tobler et al., 2011 cited in O'Keefe et al. 2016; Popek & Halagarda, 2017; Hudson et al., 2015). However, Mallinson et al. (2018) concluded that UK consumers appear to be fairly ambivalent about GM food, and 54.7% willing to eat it.[3]

[3] The study surveyed 3,340 UK members of the public in 2016.

Literature on attitudes towards food from cloned animals is much less extensive, but many similar concerns to GM foods exist. This review has found that most consumers would not purchase food from cloned animals (Rollin et al., 2011; Brooks and Lusk, 2011; Schnettler et al., 2015; Aizaki et al., 2011; BEUC, 2015). Consumers are critical of cloning as a technology, and in particular, feel that cloning for food production is unjustifiable (BEUC, 2015). Some people have ethical concerns and consider cloning as morally wrong (Rollin et al., 2011). Other concerns relate to the unknown long-term effects and labelling of food from cloned animals (Britwum et al. 2018; Rollin et al. 2011), together with cost effectiveness and potential trade implications (Murphy et al., 2011). Interestingly, research looking at expert predictions of consumer views (Murphy et al., 2011; Saeed et al., 2015) were largely negative with this believed to be due to associations with human cloning and animal welfare.

Findings related to public attitudes towards nanotechnology in food show neutral, often weak or somewhat ambivalent opinions that vary between individuals (Fischer et al., 2013; Santeramo et al., 2018). This could be related to the limited knowledge and awareness of the technology (NanOpinion, 2014). Researchers have reported that media information about nanotechnology in food is severely limited (Dudo et al. 2011 cited in Yue et al., 2015) and that public awareness is low with 62% of Americans hearing only the term or nothing at all about nanotechnology (Harris, 2012 cited in Yue et al., 2015).

For some emerging technologies such as alternative protein sources like cultured meat and entomophagy (insects as food for human consumption), consumers have expressed that they would be willing to try it but would not be willing to consume regularly or choose it over conventional meat/protein sources (Bryant & Barnett, 2018; Hartmann & Siegrist, 2017a). Survey data in the UK indicates that about 16% - 19% of consumers would eat cultured meat, 42% - 62% would not, and 19% - 40% are undecided (The Grocer, 2017; Surveygoo, 2018; YouGov, 2013). Consumers are generally aware of the benefits, particularly societal and environmental benefits, but are still concerned about personal risks to themselves as consumers. Again there are perceptions of unnaturalness associated with these technologies (Verbeke, Marcu et al., 2015).

Although it is quite common in some countries in Asia, Africa and South America, literature has shown that eating insects as food has provoked both disgust and intrigue in Western consumers (Clarkson et al., 2018). Some literature also suggests that younger consumers are more accepting of insects as food (Collins et al., 2019; Caparros Megido et al., 2016).

The scarce literature on consumer views towards 3D printed food indicates that the general public tend to have low levels of knowledge and familiarity and negative attitudes towards 3D printed food technology, though this is not universal with some sub-samples of people (for example, university staff and students, Mantihal et al., 2019) being reasonably familiar and positive (Brunner et al. 2018; Lupton, 2018a,b,c, Mantihal et al. 2019).

For cultured meat, nanotechnology in food, and 3D printed food, many consumers feel at a personal level that these technologies are unnatural (Conti et al., 2011; Casolani et al., 2015; Kohler and Som, 2008; Becker, 2013; Simons et al., 2009, cited in Gupta et al., 2017; Verbeke, Marcu et al., 2015, Lupton & Turner, 2018b,c). In the case of cultured meat this sometimes underpins a disgust response (Verbeke, Marcu et al., 2015). Other personal concerns consumers share towards these technologies relate to food safety and healthiness (Bryant & Barnett, 2018; O'Keefe et al., 2016; Verbeke, Marcu et al., 2015; Conti et al., 2011; Casolani et al., 2015; Kohler and Som, 2008; Becker, 2013; Simons et al., 2009, cited in Gupta et al., 2017; Verbeke, Marcu et al., 2015; Lupton & Turner, 2018c). For example, assumptions that 3D printed food would somehow be 'plastic' and therefore inedible (Lupton & Turner, 2018c). For 3D printed food, the extent of processing is a key concern for many participants (Lupton & Turner, 2018c). Consumers also raised concerns for the taste and quality of cultured meat. At a societal level concerns about the loss of farming, energy consumption, and suspicion of corporate drivers were also raised in relation to cultured meat (Verbeke, Marcu et al., 2015; O'Keefe et al., 2016).

It is important to note that all of the studies looking at consumer acceptance of cultured meat, similar to food from cloned animals, are hypothetical as it is not currently available on the market. Therefore authors point out that in practice, willingness to purchase/consume cultured meat would depend on factors such as price, product quality, and popularity, which cannot currently be accounted for (Bryant & Barnett, 2018).

It has not been possible to generalise consumer attitudes towards functional foods as a whole in these findings given the range of foods included under this category. This has also been argued previously in a review by Özen et al. (2012) cited in Küster-Boluda & Vidal-Capilla (2017). Views appear to vary depending on the functional food product in question (Sandmann et al., 2015; Shan et al., 2017; Barrena & Sanchez, 2010; Bimbo et al., 2017; Kuster-Boluda & Vidal-Capilla, 2017). The findings from this review demonstrate that consumer attitudes towards a functional food product depend on the perception of the overall health benefits, the necessity of the final product, and the combination of carrier product and added ingredient. However, unlike the other technologies included in this review, there does not appear to be any strong objections to the production of functional foods.

Similar to public views of functional food, there is also a mixed and rather partial picture in terms of public views of synthetic biology applied to food. However, there is some evidence of negative views that follow similar lines to those of GM technology. These include concerns about potential environmental and human health impacts, moral, emotional or value-related issues such as ‘unnaturalness’, ‘creating life’ and ‘playing God’, together with increased control of technology and patents by large companies (Betten et al., 2018; Hart Research Associates, 2013; Mandel et al., 2008 cited in Jin et al., 2019). However, these are perceptions of synthetic biology per se rather than of specific applications. It is argued that negative responses to technological innovation should not be portrayed as normative across consumers (Frewer, 2017) and that there is little evidence showing an ‘inherent societal aversion’ to synthetic biology as an enabling technology (Jin et al., 2019). Instead public acceptance of synthetic biology is likely to depend on the application and context (Frewer, 2017; Jin et al., 2019).

Some studies noted consumer concerns about adequate regulation and the presence of clear and transparent labelling in order to make informed purchase decisions in regard to food technologies. This was particularly a concern for food from cloned animals (Britwum and Bernard 2018; Rollin et al. 2011), cultured meat (Bryant & Barnett, 2018; O’Keefe et al., 2016; Verbeke, Marcu et al., 2015), GM foods (Popek and Halagarda, 2017) and 3D printed food (Lupton & Turner, 2018a). For GM foods, those who indicate negative views towards GM foods showed considerably more support towards the idea of GM food products labelling (Popek and Halagarda, 2017). This has also been found to be the case with nanotechnology applied to foods (Yue et al., 2015).

How do views differ depending on the type of technology?

Key findings across the technologies:

- Attitudes vary within each technology depending on the type of application and the context.
- Functional foods appear to evoke most positive attitudes especially when there is a focus on health benefits.
- Novel food processes – eating insects or food derived from insects, whilst in some cases creating a disgust reaction seems to arouse interest and potential for acceptance.
- Cultured meat and food from a cloned animal findings suggest a minority of people would eat them.
- With respect to nanotechnology there were mixed views with some research suggesting attitudes were more

positive than GM foods, but others showing that was not the case.

- GM food was largely viewed negatively: it was felt that its initial negative image has not been reduced over time although more information on benefits as well as risks has been developed.
- Attitudes to synthetic biology, in part were similar to those of GM foods but there is much less research and it varies according to application and whether the type of synthetic biology is making more (bottom-up) or less (top-down) fundamental changes to biological processes.
- Attitudes among general public towards 3D printed food tend to be negative, though this is not universal, and information had been found to have a positive impact on the attitudes of some study participants.

Attitudes towards different applications of the same technology

The findings of the REA show that for some technologies, consumer acceptance varies depending on the product or application of that technology.

Attitudes towards the use of GM animals, particularly in food production, are more negative than those towards GM plants and non-specific GM applications (Frewer et al., 2013; Frewer, Coles et al., 2014). These views seem to be based on perceptions of risk, benefits, ethical concerns and unnaturalness (Frewer, Coles et al., 2014). With respect to nanotechnology there is some evidence of greater perceived benefits from external applications, for example, in packaging rather than in food products (Siegrist et al., 2007; Siegrist et al., 2008; cited in Frewer, Gupta et al., 2014; Stampfli et al., 2010, cited in Gupta, 2017; Brown & Kuzma, 2013 cited in Yue et al., 2015), but also some evidence for the contrary, where benefits of in-food applications of nanotechnology are perceived greater (Zhou & Hu, 2018).

Although the literature suggests that the same pattern of consumer acceptance is expected for food applications of GM as is for other (for example medical/pharmaceutical) applications (Frewer, Coles et al., 2014), evidence suggests that there is greater public acceptance for applications of animal cloning and synthetic biology technologies outside of agri-food. For example, cloning used for the preservation of endangered species (Eurobarometer, 2008 cited in BEUC, 2015) and human health (medicine), energy and environmental applications of synthetic biology (Jin et al., 2019), may be received more positively by the public than agrifood applications. As noted, attitudes towards GM animals for food appear to be more negative than for GM plants (Frewer et al., 2013; Coles et al., 2015), and non-food applications of GM animals raise few societal objections as long as animal welfare standards are addressed (Coles et al., 2015). There also appears to be more support for cisgenics (within species) than transgenesis (between species) (Gaskell, et al., 2011; Hudson et al., 2015).

For some technologies, views also seem to vary depending on characteristics of the product. For example, evidence suggests that acceptance of insects as food depends on the nature and presentation of the insect food product. Consumers have been found to be more accepting when insects are less visible in the food (Collins et al., 2019). They have also been found to be more accepting of insects in a sweet snack or breakfast option, rather than as a meat substitute in a main meal (Clarkson et al., 2016).

Similarly, recorded attitudes towards functional foods depended on specific product attributes. For example, consumers perceived the healthiness of enriched processed meat products differently depending on the base product, with cured whole muscle cuts being perceived as healthier than processed meat products (for example sausage-type products) (Shan et al., 2017). Willingness to consume functional foods was greater amongst consumers when the match between carrier and added functional ingredient is more ‘natural’ (for example calcium being added to yoghurt versus omega-3 added to yoghurt) (Bimbo et al., 2017). Familiarity with the products may also be a factor, for example Çakiroğlu & Uçar (2018) found that among Turkish consumers ‘kefir’ and ‘fat-reduced yoghurts’ were the most purchased and consumed functional foods amongst a range of milk and dairy products. The authors point out that yoghurt and kefir originate in the part of the world where this study was conducted so these products would already be consumed by participants regularly, therefore this might be why these products received high acceptance.

Willingness to try 3D printed foods and serve it to others has been found to vary considerably depending on the food product. That is, a greater acceptance of foods already considered as highly processed and ‘unhealthy’ (for example chocolate, pasta etc), and much less so for food considered ‘healthy’ and ‘natural’ foods (for example such as meat, vegetables) (Lupton & Turner, 2018a,b). Consumer acceptance of 3D printed cultured meat and insect-based foods was also found to be very low, despite the technology being proposed as a way to make these products more appealing to consumers (Lupton & Turner, 2018a,b).

Alternatively, the type of product does not seem to influence consumer acceptance of food from a cloned animal. Findings from the reviewed literature found virtually no difference in willingness to eat meat and willingness to drink milk from a cloned animal (Brooks & Lusk, 2011).

Similarities and differences in attitudes between technologies

Several comparisons are made between different emerging food technologies and GM foods. For example, Avellaneda and Hagen (2016) cited in Frewer (2017) confirm that the factors which influence public perceptions of synthetic biology are almost identical to other enabling technologies, most notably genetic modification. Rollin et al. (2011) also found similarities in terms of consumer awareness and acceptance between GM food and food from cloned animals. In addition nanotechnology appears to be often compared with GM food, however the research on attitudes to nanotechnology has been much more limited, but more positive (Frewer et al., 2002; Pidgeon et al., 2003; Scheufele et al., 2007; all cited in Frewer, Gupta et al., 2014; Kuzma, 2017). Consumers have been found to be willing to pay more to avoid GM foods than nanotechnology in food (Yue et al., 2014 cited in Yue et al., 2015). Further, consumers' trust in government did not affect participants support for policies restricting nanotechnology in food but did affect the same measure for GM food.

One study suggests that nanotechnology industry and regulators have learnt lessons from the experience of GM by recognising the importance of consumer perception of personal and societal benefits from a technology (Frewer, Gupta et al. 2014). However, Gupta et al. (2017) suggest that having a narrow focus on parallels with GM foods may be misleading, as consumers today form their decisions on the acceptability of the use of technologies in the food industry based on a multitude of factors.

Several studies on cultured meat also draw analogies with public views of GM foods, for example Bryant & Barnett (2018) show similarities in demographic trends in acceptance of the two technologies. However O'Keefe et al. (2016) found that people generally perceived cultured meat more positively than GM foods.

In a review of several alternative proteins including cultured meat and insects as food, Hartmann and Siegrist (2017a) conclude that acceptance of each option varies based on product attributes, meal context and previous experience.

Brunner et al. (2018) report that consumer responses towards 3D printed food in their empirical study are similar to those reported elsewhere for other novel food technologies that with similar benefits.

What shapes the public's views?

Key factors that shape views include:

- Contextual factors such as previous societal experience of novel foods such as GM foods.
- Risk perceptions such as naturalness (all technologies) and controllability of effects (GM foods, nanotechnology, synthetic biology).
- Food governance: how the food is regulated, who benefits from the technology and trust in the institutions developing the technologies (all technologies).
- Individual characteristics such as knowledge/information which have been shown to link with increased acceptance in some cases (for example cultured meat, insects as food, GM food, 3D printed food) but not others (for example food from a cloned animal).
- Framing of information has also shown to affect attitudes towards technologies (for example cultured meat, synthetic biology).

Contextual factors

Contextual factors such as previous experience of novel foods and perceptions of the efficacy of legislative and regulatory arrangements for managing the food system can be important (Rollin et al., 2011). The experience of the introduction of GM foods is considered to have influenced perceptions of many other emerging food technologies such as animal products from cloned animals (Britwum and Bernard, 2018). In the case of novel foods such as insects, the public's views are largely shaped by the social context and degree of familiarity with insects as food and by the way in which the insects or their protein are presented. The recent, wide media attention to aspects such as sustainability, health, nutrition have increased familiarity rapidly (Collins et al., 2019).

Factors contributing to create or reinforce negative views of nanotechnology in foods include the lack of perceived societal or consumer benefits and the perception that there are hidden vested interests on the part of industry and institutions (Gupta et al., 2017).

Risk perceptions

The review suggests that consumer perceptions that risks associated with emerging food technologies are involuntary (i.e. the person doesn't have a choice whether or not take that risk), unnatural, unknown to scientific experts, 'hidden' by regulatory institutions or may affect health rather than the environment, can influence consumer attitudes (Gaskell, 2000; Siegrist et al., 2008; Slovic, 1987; van Kleef et al., 2006; cited in Rollin et al., 2011). Concern about risks was identified as an important factor that continues to influence views of GM foods (Bongoni, 2016; Popek and Halagarda, 2017).

Further, Dragojlovic and Einsiedel (2013) found that that putting an ‘unnaturalness objection’ into a newspaper article about synthetic biology activated that perception when the perceived evolutionary distance between the biological material and its host is large, for example human-yeast, but was not effective when the evolutionary distance is small, for example plant-yeast. The impact of ‘unnaturalness’ framing is likely to differ depending on people’s underlying values, for example how far they link naturalness with goodness.

Frewer, Coles et al. (2014, p.1303) state that ‘underlying risk perceptions inform consumer attitudes’. In the case of GM foods, consumers were found to seek to avoid unforeseen and unspecified risks, as these risks create anxiety related to an uncertain future (Bongoni, 2016). However, Bongoni (2016) also indicates that material benefits can outweigh risk perceptions related to GM products, as people tend to ignore risks if they perceive material benefits. In relation to material benefits, price is said to be the most important consideration (Twardowski & Małyska, 2015, cited in Bongoni, 2016).

The importance of presenting benefits of emerging food technologies alongside risks is reported to be one of the main lessons (Frewer, Coles et al., 2014) from the experience of negative public response to GM foods. Frewer, Coles et al. (2014) suggest this has influenced public discussion of other emerging food technologies. The potential health benefits of using nanotechnology in foods was found to influence perceptions (Kuzma, 2017; Santeramo et al., 2018). Kuzma reports that the strongest factor was the consideration of health and nutrition benefits for the poor and elderly and suggests that this could be termed an ‘altruism’ benefit, to differentiate it from perceived benefits to the individual (Kuzma, 2017).

Bryant and Barnett (2018) indicate that the provision of information (both positive and negative) had an effect on consumer attitudes towards cultured meat in an experimental study in the Netherlands (Bekker et al., 2017 cited in Bryant and Barnett, 2018). This supports previous findings by Verbeke, Sans & Van Loo (2015). More technical descriptions of cultured meat resulted in lower acceptance than less technical descriptions in an experimental study in Switzerland (Siegrist et al., 2018). Bryant and Dillard (2019) also found that framing cultured meat as a high-tech innovation led to lower acceptance compared to framing it as having societal benefits, or being very similar to conventional meat. Similarly, Bryant and Barnett (2019) find that nomenclature has an impact on public perceptions, with names like ‘clean meat’ being more appealing than names like ‘lab grown meat’. For insect-based food products, the visibility of the insects (i.e. rather than them being used in another product) and people’s knowledge of them is a major factor in their acceptance (Collins et al., 2019).

Several authors suggest that the public perception of cultured meat is likely to be shaped by product attributes (for example taste, appearance) as well as by the perceived benefits and risks, trust in science, and media coverage (Verbeke, Sans and Van Loo, 2015; Hartmann and Siegrist, 2017a).

In the case of functional foods, consumer perceptions of the attributes of the base products (for example processed meat, yoghurt), particularly perceptions of healthiness (Shan et al., 2017; Bimbo et al., 2017) and taste (Bimbo et al., 2017) were found to influence their perception of the functional food itself.

Risk perceptions towards 3D printed food include unfamiliarity with technology and concerns about the safety, extent of processing, healthiness/nutrition and taste (Lupton & Turner, 2018b, c). Appearance of 3D printed food can also be a key factor in shaping consumer responses (Lupton & Turner, 2018c).

Food governance

The way that food is managed or governed can influence consumers’ perceptions of the acceptability of emerging technologies. Rollin et al. (2011, p.101) observed that labelling can influence the acceptance of cloned food products as ‘people are inclined to accept the risk of consuming new food products, if it is under their own control’. Gupta et al. (2017) found that clarity on the responsibilities of different actors in the food system, for example, for creating, regulating or providing information on the safety of nanotechnologies in food products was an important factor influencing consumer views. Attitudes to nanotechnology in foods were also influenced by levels of trust in the nanotechnology industry (Gupta et al., 2017; Santeramo et al., 2018). Likewise, Cheftel et al. (2011) found that trust in certain sources (for example authorities, experts, media etc.) is a crucial determinant of acceptance of novel technologies including for food from cloned animals. Having a medical authority as the source of information, for example, doctors or dieticians has been shown to increase the acceptance of functional foods (Loizou et al., 2013 cited in Santeramo et al., 2018). For 3D printed food, concerns have been expressed that the technology could be used in food without consumers’ knowledge, raising the need for labelling of such products to enable informed choice (Lupton & Turner, 2018a).

Individual characteristics

The characteristics of individual consumers have also been explored as a potential influence on consumer views of emerging food technologies. The extent to which knowledge about individual emerging food technologies influences consumer views is contested and evidence varies across a range of emerging food technologies (Rollin, 2011). In the case of meat from cloned animals, Aizaki et al. (2011) report that new technical information did not influence consumers' attitudes in Japan. However, Britwum and Bernard (2018) found that the more knowledgeable a person viewed themselves as being about cloning, the more accepting they were of the idea of milk from cloned animals. Bryant, Szejda et al. (2019) found that people who are more familiar with cultured meat or are given information about it are more accepting of the technology which confirms previous suggestions by Bryant and Barnett (2018). Similar differences over the way that information and knowledge influence attitudes are found in the literature on GM foods. For example, McPhetres et al. (2019) suggest that scientific knowledge and knowledge specific to GM technology may be important influences on attitudes to GM technology. They argue that negative attitudes towards GM technology are strongest in those with the least knowledge (Fernbach et al., 2019 cited in McPhetres et al. 2019). They indicate that increased lay knowledge about technological innovations is likely to be associated with more positive views (Li et al., 200). However other authors have been critical of this argument (see Hilgartner, 1990 cited in Frewer, Coles et al., 2014; Wuepper et al., 2018). Brunner et al. (2018) provide some evidence that informing consumers about 3D printed food technology can significantly impact attitudes for some, with attitudes becoming more positive - those with little or no previous knowledge being most impacted, whereas little or no impact on skilled participants. In their study, the provision of information was found to be successful in overcoming food neophobia, but reinforced food technology neophobia (Brunner et al. 2018). With respect to functional foods, consumption frequency (which increases with familiarity) has been shown to increase acceptance of functional foods (Shan et al., 2017).

Jin et al. (2019) report 'value predispositions', for example religiosity, deference to authority as well as trust in scientists affects publics' views of synthetic biology (Akin et al., 2017 cited in Jin et al., 2019). Deference towards scientific authority refers to the belief that the scientific enterprise is for the public good. It is found to correlate with acceptance of technologies such as synthetic biology and nanotechnology, whilst trust has been defined as the short-term and individual confidence in scientists' motivation and competency.

The relationship between individuals' knowledge about healthy diets and their acceptance of emerging food technologies is contested. A systematic review of consumer acceptance of fortified dairy products concluded that many studies into this relationship have used non-validated scales and that further research is therefore needed (Bimbo et al., 2017). Interest in and adoption of healthy lifestyles was not found to positively influence willingness to consume functional foods (Kuster-Boluda

& Vidal-Capilla, 2017). This supports findings of previous studies that, interestingly, emphasise a negative relationship between healthy lifestyles and willingness to consume functional foods (Siro, Kapolna, and Lugasi, 2008; Poppe & Kjærnes, 2003 cited in Kuster-Boluda & Vidal-Capilla, 2017; Goetzke & Spiller, 2014). In a comparison of consumers of organic food and consumers of functional foods Goetzke & Spiller (2014) found that both groups have the same concept of health and well-being. However, the groups differ in pathways to its achievement with consumption of organic foods associated with active lifestyles and consumption of functional foods associated with passive lifestyles to improve health.

The influence of socio-demographic factors is explored further in the next section.

Do different types of people hold different views?

Key findings

There is some limited evidence that consumers' attitudes can vary in terms of the following factors, however findings cannot be generalised given the small number of studies and the mixed findings:

- Gender: men more accepting/positive towards cultured meat, food from a cloned animal, nanotechnology, synthetic biology and 3D printed food.
- Age: younger people more accepting of insect eating, cultured meat and food from a cloned animal but no effects for 3D printed food or synthetic biology. Older people more likely to buy functional foods.
- Education: higher education has some relationship to positive attitudes towards cultured meat, GM foods and food from a cloned animal, synthetic biology and nanotechnology.
- Household structure, as well as cultures and countries, urban vs rural, and other lifestyle and experience factors also relate to consumer views.

Gender

There is some evidence that gender plays a role in explaining attitudes towards cultured meat (Bryant and Barnett, 2018), food from a cloned animal (Aizaki et al.

2011; Britwum and Bernard 2018, Brooks and Lusk, 2011), and nanotechnology (Fischer et al., 2013). While evidence on the role of gender is mixed for several technologies, namely, functional foods (Bimbo et al. 2017)[4], synthetic biology (Jin et al., 2019), GM foods and 3D printed foods (for example, Mantihal et al., 2019 and Brunner et al. 2018). Indeed, Jin et al. (2019) find that in larger quantitative studies on attitudes to synthetic biology gender differences become insignificant as has been the case with GM technologies (Akin et al., 2017; Frewer et al., 1996; Kahan et al., 2009; Verdurme & Viaene, 2003 cited in Jin et al., 2019). No substantial effect of gender has been found for eating insects (Hartmann and Siegrist, 2017b; Collins et al., 2019).

Where gender differences have been identified the impact varies between technologies: in general men have been found to be more accepting of cultured meat than women (Bryant and Barnett (2018), more likely to believe that cloned meat is safe for consumption (Aizaki et al. 2011; Britwum and Bernard 2018, Brooks and Lusk, 2011), to perceive lower risks from synthetic biology (Mandel et al., 2008 cited in Jin et al., 2019), to be more positive to nanotechnology in foods following the provision of information (Fischer et al. 2013) and to have more positive initial attitudes to 3D printed foods (Brunner et al. 2018)[5]. Whereas for functional foods, female consumers have been found to be more willing to consume these (Bimbo et al. 2017). Further, Kraus et al., 2017) found that women value the functional components more than men. Women, older people, and those with a university education attributed the greatest significance to naturalness, nutritional value, freshness, food safety, and quality guarantee[6] of functional foods (Kraus et al., 2017).

Age

There is some evidence that age plays a role in shaping attitudes towards cultured meat (Slade 2018) and novel foods specifically insect-based foods (Collins et al., 2019). The evidence is mixed on whether or not age has an impact on attitudes to functional foods and food that is from a cloned animal[7]. Age was not found to be significant in explain attitudes to 3D printed food (Brunner et al. 2018, Mantihal et al., 2019), nor to influence the overall perception toward rice as ethical developed from

[4] For example, Bimbo et al (2017) find gender explains differences in acceptance of functional dairy products, whereas Ozen et al (2012, 2014) concluded it was not possible to identify the influence of such factors on consumption of functional food

[5] Brunner et al (2018) found gender to be significant in explaining the initial attitudes of Swiss consumers to 3D printed food, with men showing a more positive attitude than women, although gender was not significant in explaining attitude changes at the end of the survey.

[6] Perceived quality attributes assessed in the questionnaire were organoleptic (sensory)attributes and attributes of packaging and labelling

[7] For example, Bimbo et al (2017) find age explains differences in acceptance of functional dairy products, whereas Ozen et al (2012, 2014) concluded it was not possible to identify the influence of such factors on consumption of functional food. And Britwum et al. (2018) find age-related difference in views towards food from cloned animals, whereas Schnettler et al. (2015) did not find any significant differences in consumer acceptance across different age groups.

synthetic biology (Amin et al. 2013 found that all ages found the rice modified with mouse genes to be not very acceptable ethically).

Where age has been identified as influencing attitudes the impact varies according to the technology: younger consumers are more likely to eat cultured meat (Slade, 2018; Eurobarometer, 2005; YouGov, 2013; Surveygoo, 2018; The Grocer, 2017) and are more supportive of food from cloned animals than older generations (Britwum et al. 2018) and children are slightly more open to ‘first tries’ of novel foods specifically insect-based foods (Collins et al., 2019). In contrast willingness to purchase and consume some functional foods has been found to increase with age (Bimbo et al., 2017). Young men were found to attach less importance to the health benefits of purchasing functional food which was explained possibly because they enjoy good health and were generally less interested in healthy diets (Kraus et al., 2017).

Education and knowledge

There is some evidence that education plays a role in attitudes towards cultured meat (Slade, 2018), GM foods (Popek and Halagarda, 2017) and nanotechnology (Fischer et al., 2013). However, evidence is mixed on whether or not education has an impact on attitudes to food from cloned animals (for example, Brooks and Lusk, 2011 and Schnettler et al., 2015) and synthetic biology (for example, Jin et al., 2019 and Amin et al. 2013). Education was not found to be significant in explain attitudes to 3D printed food (Brunner et al. 2018, Mantihal et al., 2019) or functional food (Ozen et al., 2012, 2014).

Where education has been identified as influential there is consistency in the nature of the impact. More highly educated people are more likely to eat cultured meat (Slade, 2018), to hold positive views towards GM foods (Popek and Halagarda, 2017), to be more supportive of food from cloned animals (Brooks and Lusk, 2011) and of synthetic biology (Jin et al., 2019). Higher levels of education are also related to more positive attitudes towards nanotechnology in foods following the provision of information (Fischer et al. 2013). Having a scientific education has also been found to be positively associated with GM food acceptance (Mallinson et al., 2018; Hudson et al., 2015). Those with better knowledge of GM foods tend to hold more positive views toward the use of this technology (Popek and Halagarda, 2017).

Household structure

Evidence suggests that household structure has an impact on views towards functional foods (Barrena & Sanchez, 2010) and food from cloned animals (Brooks and Lusk, 2011). Barrena & Sanchez (2010) found that in relation to the cognitive purchasing decisions of functional foods, while consumers from both households with children and without children were interested in some functional consequences of purchasing a product, only consumers from households with children were interested in different attributes and functional qualities in comparison with households without children. With respect to functional foods a number of socio-cultural factors have been found to influence acceptance (Santeramo et al., 2018). Specifically, family structure and circumstances seem to play a role. Functional food acceptance increases with the presence of an ill family member (Loizou et al., 2013 cited in Santeramo et al., 2018), and the presence of children in the household (Bechtold & Abdulai, 2014 cited in Santeramo et al., 2018). For food from cloned animals, views have been found to vary according to the age of the children present, with households with young children being less accepting than those with children over the age of 12 (Brooks & Lusk, 2011).

Ramsay et al. (2014) found that found that pregnant women and women contemplating pregnancy expressed a reluctance to use probiotics. The authors suggest that this is due to a lack of understanding of the safety and benefits of probiotics foods during pregnancy. In contrast, women not contemplating pregnancy were most likely to consume probiotics concurrently with vitamin supplements.

Differences between cultures and countries

Acceptance of cultured meat has been found to differ between European countries (Eurobarometer, 2005) and also between UK and USA, with substantially higher acceptance in the USA compared to the UK (Surveygoo, 2018). Europeans have been shown to be generally against the consumption of GM foods in comparison to Asian and US consumers (Fewer et al. 2013). Europeans have been shown to believe they are risky, not useful, and should not be encouraged, while Asians have been shown to be more positive. It is suggested this is influenced by a more positive attitude in developing countries towards the benefits of scientific development and innovation (Bongoni, 2016). Differences may also be explained in part by the differing views of countries towards GM technologies (Popek and Halagarda, 2017). For example, marketing of GM is (reportedly) restricted in Poland (see Bongoni, 2016 cited in Popek and Halagarda, 2017), while the British government considers 'the biotechnology sector as one of the key national strengths contributing to the development of the UK economy' (Cocklin et al., 2008 cited in Popek and Halagarda, 2017). French consumers were less willing to accept nano-packaging than nano-fortification with vitamins, whereas German consumers held the opposite views (Bieberstein et al., 2013). This may be due to differences in prior beliefs and familiarity linked to long-term country-specific traditions, or differing roles of the state in consumer protection, but suggests that there is a nuanced picture around the acceptance of different nanotechnology applications.

Urban-Rural

Several studies have found urban-dwelling consumers to be more positive or accepting than more rural-dwelling consumers towards cultured meat (Tucker, 2014; Shaw & Mac Con Iomaire, 2019) and cloned food products (Schnettler et al. 2015; Britwum and Bernard, 2018).

Political views, personality traits/lifestyles, and other factors

In general, politically liberal people have been found to be more accepting of cultured meat than those with more conservative views (Wilks & Phillips, 2017). Higher consumer acceptance of cloned food products has been observed amongst environmentally aware left-leaning individuals (Britwum and Bernard, 2018). In a small sample of Australian residents, most of those willing to consume 3D printed food considered themselves to be ‘adventurous eaters’. Vegetarians have been shown to be more likely to have positive views of cultured meat compared to omnivores, but are less likely to want to eat it themselves (Flycatcher, 2013; Wilks and Phillips, 2017; Bryant, Szejda et al., 2019). Higher consumer acceptance for cloned food products has been observed amongst primary grocery shoppers i.e. those who do the main shopping in a household (Britwum & Bernard, 2018). ‘Green shopping’ indicates greater receptivity towards novel foods specifically insect-based foods (Collins et al., 2019). Previous experience (often associated with travel or cultural background), and regular exercise patterns indicate greater receptivity towards novel foods specifically insect-based foods (Collins et al., 2019).

How do views affect behaviour such as food choices?

Key findings:

- No papers reviewed measured actual purchasing behaviour, but focussed on willingness/intention to eat/buy. Perceptions of health benefits and positive attitudes were linked to intentions to buy functional foods.
- Consumers were less likely to indicate an intention to buy once they knew the product was food from a cloned animal, and cultured meat burgers were least likely to be bought than plant based burgers or conventional meat burgers. Views on the environment and animal ethics were related to these decisions.

- Price has an effect, with people more willing to buy GM foods if available at a reasonable price.
- Having a 'green' healthy lifestyle is linked to willingness to eat insects.
- Consumer preference for labelling of nanotechnology food applications is positively linked to their willingness to buy, but this is not the case for GM foods.
- Little evidence of consumer willingness to incorporate 3D printed food into everyday food choices.

Across all the technologies there were no papers reviewed that measured actual purchasing behaviour. This is somewhat understandable as for 3 of the 8 technologies examined 3 (cultured meat, meat from a cloned animal, and nanotechnology food applications) there are no products available for every day purchase. Some of the technologies are in production but not yet available to buy in the UK including: synthetic biology, for example, EverSweet Real Vegan Cheese)[8]; cultured meat, for example, Mosameat[9]; Insects[10]; and synthetic biological meat substitutes, for example, 'Impossible' meat[11]. GM foods[12] are available in the UK although limited in variety and availability. Technology for home printing of 3D printed chocolate is available in UK[13]. There is also a variety of functional foods that are widely available in the UK. Novel applications of nanotechnology is available in some food products but not in the UK[14].

Where papers have looked at behaviours, for most technologies they focus on behavioural intention to eat a food from the specific technology. The exceptions are synthetic biology and nanotechnology where there were no papers that looked at behaviours. Instead for these technologies the focus was on risk perception, and acceptance in more general terms.

In terms of how views affect behaviours, with respect to functional foods, Shan et al. (2017) cite previous literature that suggested positive attitudes towards functional foods is a significant predictor of the purchase intention and overall spending on this type of food (Carrillo et al., 2013; Patch et al., 2005 cited in Shan et al., 2017). More specifically, positive attitudes towards their necessity, their benefits, confidence in

[8] Real Vegan Cheese and Cargill
[9] mosameat
[10] It is possible to buy insects on line and Sainsbury's BBQ crickets in some of their supermarkets from Autumn 2018.
[11] Impossible burgers
[12] UK imports oilseed rape, soybean, cotton-seed oil, maize and sugar beet that is GM but does not cultivate any GM crops.
[13] See http://chocedge.com/home.html
[14] In Australia for instance, nanocapsules are used to add Omega-3 fatty acids to one of the country's most popular brands of white bread https://www.nanowerk.com/spotlight/spotid=1360.php

their effects and their safety increased a sample of Spanish consumers' willingness to consume a range of functional foods (Kuster-Boluda & Vidal-Capilla, 2017). A related finding comes from Shan et al. (2017) who conclude that attitudes towards and health perceptions of processed meat were the main drivers of intention to purchase enriched processed meat, rather than more general food choice motivations and differences between socio-economic groups.

There are some similarities between attitudes and their links to behavioural intentions across meat from cloned animals and cultured meat. From a web-based survey Brooks and Lusk (2011) found that approximately 40% of consumers would likely alter their purchasing behaviour, i.e. not buy the product, if they learned that the food came from cloned animals. Britwum et al. (2018) found that consumer willingness to purchase food from cloned animals was influenced by personal concerns about the environment and animal welfare.

Aizaki et al. (2011) conclude that consumers 'would not welcome the use of animal cloning in food production' considering they have a greater support for conventional products. Likewise, BEUC (2015) highlight that majority of EU consumers have expressed unlikeliness to buy food from cloned animals regardless of its safety standards. Two studies used choice experiments to observe hypothetical choices between cultured meat, plant-based meat substitutes, and conventional animal meat showed that the lowest percentage of consumers would choose a cultured meat beef burger (4% Slade, 2018 and 5% Lusk, 2019) when price was controlled for.

Interestingly, for GM foods price is a key factor in an observed divergence between consumer attitudes and their actual behavioural intentions. Specifically, there is evidence that 61% of Europeans do not support GM food products (Gaskell et al., 2010 cited in Popek and Halagarda, 2017). However, when making everyday purchasing decisions Europeans still tend to buy GM foods, despite stating reluctance in surveys or questionnaires. Popek and Halagarda, (2017) mention a study by Siegrist (2008) which suggests that the majority of British consumers would purchase a GM food if it was available at a certain price. Price can be seen as a possible driver of behaviours in the study by Britwum et al. (2018) where consumers who considered food price in their purchasing behaviour were more accepting of food from cloned animals than those for whom price was not an issue. Looking at GM foods and nanotechnology in food, Yue et al. (2015) found that trust in government regulation was indirectly and positively related to the willingness to buy those products. Labelling appears to have mixed effects on consumer preferences. In the case of nanotechnology food applications labelling appears to be positively linked to consumer's willingness to buy, but this is not the case for GM foods (Yue et al., 2015).

Rollin et al. (2011) suggest that price, alongside taste and convenience are the main factors affecting consumer food purchasing behaviour including products from novel technologies (Bruhn, 2008; Fell et al., 2009; Spence & Townsend, 2006; Bruhn, 2008; Food Marketing Institute, 2005 cited in Rollin et al., 2011). Cost and quality was also cited as the primary influence for Irish stakeholders in food purchase decisions rather than ethical concerns (Murphy et al. 2011).

In relation to novel food processes and specifically the example of insects, the demographic groups identified as most likely to purchase insect-protein products are those already somewhat invested in ‘green’ and ‘healthy’ lifestyle choices. Being a meat-eater rather than vegetarian also promotes purchase and consumption (Collins et al., 2019).

Finally for 3D printed food, it is suggested that key aspects to promote to consumers include ‘fun to use’, convenience, health and personalised nutrition (Brunner et al. 2018), while consideration should also be given to food content, the sensory qualities, level of processing (Lupton & Turner, (2018a).

How have views changed over time?

Key findings:

- Research into consumer attitudes towards food from cloned animals suggests that they have not changed since 2009 and are still negative, but are now more formed than in 2009 when a large proportion of public did not have a firm view.

- Attitudes towards synthetic biology as an area of technology (rather than as applied to food) seem to be similar to those for other emerging technologies, and specifically GM technologies, and have not changed since 2009. However, the limited studies on specific food applications of synthetic biology suggest a nuanced and context dependent picture.

- Views of functional food vary depending on the combination of ‘carrier’ food and added functional ingredient. This reflects the findings in 2009, as do findings that women and older people are more favourable towards functional foods.

- Research on GM foods and consumer views has continued over the past decade but is not as active. Views are still negative in general.

- Views of nanotechnology appear to be mixed, both negative and positive which suggests some change compared to 2009 where it was reported that awareness was low but views were generally positive.

Across the eight technologies longitudinal studies have only been conducted for GM technology and cloned food products, and none of these include UK consumers. There is some evidence that in some European countries views towards GM technology have become increasingly negative. For example in Poland in 1999, about a third of Polish citizens opposed the use of biotechnology methods in food production, whereas in 2010 this rose to almost 60%. At the same time the number of people supporting GM has declined from 47% to less than 30% (Twardowski & Małyska, 2012 cited in Popek and Halagarda, 2017). With respect to cloned animals, Brooks and Lusk (2011) highlight opinion polls in the US that have shown increased consumer acceptance of cloned food products in a short period of time (2005-2008).

Other studies extrapolate from current findings. For example, in relation to cultured meat there is some evidence to suggest that views will become more positive over time. Verbeke et al. (2015) observed focus group participants becoming more positive as they discussed the topic, while O'Keefe et al. (2016) observed participants drawing analogies to microwave meals as another food technology which once seemed improbable. Bryant and Barnett (2018) comment that acceptance of cultured meat in the future will be driven by increased familiarity, increased perceived feasibility, regulation, commercial availability, media coverage and the ability to try cultured meat.

Schnettler et al. (2015) anticipate that lower acceptance among young people will prevent attitudes towards food from cloned animals becoming more positive over time, once they become primary grocery shoppers for their households. However, this assumption is in contrast with the observations of Britwum et al. (2018) who found young people more supportive of food from cloned animals than older generations.

Bimbo et al. (2017), suggest that consumer demand for functional foods and nutrition-modified foods (for example, foods with added fibre) has increased rapidly over the recent decade.

Comparing the current findings with the FSA review from 2009, a number of aspects can be drawn out:

- Research into consumer attitudes towards food from cloned animals suggests that they have not changed since 2009, and remain unsupportive. Similar reasons for this scepticism among consumers remain, including concerns about food safety, animal welfare and ethical concerns. From this review it appears that in the EU consumer views on this technology are now more formed, with a 2010 survey finding that 'Europeans have strong reservations about animal cloning in food production and do not see the benefits, and feel that it should not be encouraged' (Eurobarometer Special Report on Biotechnology, 2010, cited in BEUC, 2015, p.7). This contrasts with the findings of the 2009 review (FSA, 2009) which highlighted that a large proportion of the public did not have a firm view.

- There are now papers that examine consumer views of food applications of synthetic biology whereas there were none directly focussed on these applications in 2009, perhaps reflecting the growth in technology readiness for commercial applications of synthetic biology in food.
- As suggested in 2009, attitudes towards synthetic biology in general (rather than for specific food applications) do seem to be similar to attitudes towards other emerging technologies, specifically GM technologies. However, the limited evidence that examines specific applications including food applications suggests this is nuanced, and context dependent and that care should be taken not to assume that negative views are normative.
- Similar to the findings of the 2009 review we have found that views of functional food vary depending on the combination of carrier product and added functional ingredient (FSA, 2009). Similarly this review also finds that women and older people appear to have more positive attitudes towards functional foods (Bimbo et al., 2017; FSA, 2009).
- The literature on consumer attitudes to functional foods resembles that of the 2009 review as it still generally focuses on particular products in particular locations which makes it difficult to draw general conclusions. Overall, however, functional foods still do not tend to elicit particularly negative or hostile public attitudes[15].
- Research in public attitudes to GM does not seem to be such an active research area in 2019 as compared with the 2009 review, perhaps because other emerging food technologies have arisen since and become the focus for research[16]. None-the-less, perceptions and attitudes towards GM foods have still been relatively widely studied in the last decade. More recent studies appear to show that support for GM food across EU member states is declining (Gaskell et al., 2011).
- Bennett and Radford (2017), suggest that there has been little change in public knowledge of or attitudes to the use of nanotechnology in foods since the FSA report in 2009. Further, the 2009 review of consumer attitudes towards emerging food technologies found that although awareness of nanotechnologies was low, general attitudes towards them seemed fairly positive (FSA, 2009). However, the findings from this review appear more

[15] Though we note that functional foods can result from the application of different technologies (for example, nanotechnology, GM technology) which may be the source of concern or approval by consumers.
[16] The literature seems to suggest that research into a food safety issue peaks after the occurrence of a ‘crisis’, or presentation of issues in a crisis context.

mixed. Some of the literature in this review, including a UK study, suggests that attitudes towards nanotechnology in food are somewhat positive (Frewer, Gupta et al., 2014). However, there is other evidence to suggest weak, neutral or ambivalent attitudes (Fischer et al., 2013; Santeramo et al., 2018) or even reluctance towards nanotechnology in food (Bieberstein et al., 2013)

No studies were identified on how views towards 3D printed food have changed over time, and this technology was not included in the FSA 2009 review.

What are the gaps in current research?

Key findings:

- There is an identified need for more research into specific applications of food from cloned animals, GM foods, synthetic biology foods, functional foods, nanotechnology in food and 3D printed food to allow the comparison of similar dependent variables and better understanding of the factors influencing views.
- A need is identified for more detailed research looking at a greater number of factors influencing perceptions, attitudes, behavioural intentions and (in future) actual behaviours towards functional foods, cultured meat, GM foods, synthetic biology foods and 3D printed food.
- There are no existing longitudinal studies for GM foods, cultured meat and 3D printed food.
- There is a need to better understand trade-offs between perceptions of risks and benefits of emerging food technologies and their applications.

The outcomes of this review and the interviews conducted show the following gaps across the emerging technologies:

- A need for research focusing on specific applications of technologies was identified for food from cloned animals (for example, acceptance of food from cattle clones or from offspring of a cloned animal, and generally expanding range of products from cloned animals examined; Aizaki et al., 2011; Britwum et al.; 2018); GM foods (for example, attitudes towards animal-based GM foods, which are in comparison to acceptance of plant-based GM foods a lot less explored; Frewer et al., 2013); synthetic biology; functional foods (for example, looking at broader range of products; Bimbo et al., 2017); food where nanotechnology has been used (Frewer, Gupta et al., 2014); and 3D printed food (Brunner et al. 2018).

- A need to look at greater numbers of variables and factors/drivers that may influence consumers attitudes, was identified in relation to: functional food (Bimbo et al., 2017; Kuster-Boluda & Vidal-Capilla, 2017; Menrad, 2003 cited in Kuster-Boluda & Vidal-Capilla, 2017); cultured meat (Bryant & Barnett, 2018; O'Keefe et al., 2016; Verbeke, Sans & Van Loo, 2015); GM foods (Frewer et. al., 2013); synthetic biology; and 3D printed food (Brunner et al. 2018, Mantihal et al. 2019).
  Suggested factors to explore include:
    - product characteristics
    - geographical and/cultural regions
    - socio-demographic factors (for example, age, gender, education, etc.)
    - media, other rhetorical frames
    - different types of information provided (for example, messages highlighting animal welfare, or environmental, health and safety benefits or risks).
- The need for non-hypothetical studies was recognised in relation to food from cloned animals (Bimbo et al., 2017) and functional foods (Sandmann et al., 2015).
- The need for longitudinal studies observing (the changes) in acceptance of food from specific technologies over time has been highlighted for GM foods (Frewer et al., 2013) and lab grown meat (Bryant and Barnett 2018).

Other gaps mentioned in the papers specific to technologies reviewed include:

- Novel foods (i.e. insects as food): better understanding of nutritional profile; effects of their feedstock (for example, agricultural waste); (health and other) effects of long term consumption; technological treatment and processing methods; toxicological, microbial and hygienic safety; and allergic potential of insects (Hartmann and Siegrist, 2017).
- Nanotechnology: Frewer, Gupta et al. (2014) propose the following questions for research focused on specific applications of nanotechnology:
    - Do the applications to the agrifood sector meet a recognised societal or consumer need?
    - What similarities with potentially societally controversial aspects of previously applied agrifood technologies can be identified?
    - Are additional issues raised over and above those associated with other enabling technologies applied to food production?
    - How can benefits and risks be equitably distributed across all stakeholders?
    - What needs to be done to fine tune the development and implementation of agrifood applications of nanotechnologies to align

with consumer priorities, adoption and commercialisation of specific applications?

- Synthetic biology: from the papers reviewed the following specific questions were highlighted:
    - How do perceptions and attitudes in different demographic groups vary in relation to specific food applications of synthetic biology rather than in relation to a general description of the technology?
    - How are trade-offs between benefits, risks and other issues made by people during decision-making about synthetic biology food applications?
- Further research to explore consumers' attitudes towards functional food, with particular focus on countries where this is still weakly investigated was identified.
- 3D printed food: research to explore responses to different names for the technology (Brunner et al. 2018), and factors influencing decisions to purchase 3D food printers for the home (Mantihal et al. 2019).

Detailed findings

Genetically modified foods

Key findings:

- Issues related to GM foods include: ‘unnaturalness’, unknown risks, lack of perceived benefits, potential ‘unavoidability’ of risks, health implications, the motivations of those promoting the technology and a sense of fatalism over the expansion of GM food.
- Attitudes towards animal based GM foods are more negative than towards plant based GM foods.
- Factors that influence the public’s perceptions of GM foods include: trust in research and institutions, scepticism; knowledge, information and media; education; gender; age; living environment.
- Views on GM foods differ across global cultures and between people.
- Price seems to play a key role when it comes to purchasing decisions.
- Looking across more recent reviews and empirical research the general picture appears largely similar to that presented in 2009.

Overview of literature

Of the 11 papers included in the in-depth review, three were based on reviews of literature, five were empirical and three a mixture of empirical and review. Of the empirical papers one was quantitative and four were mixed.

The empirical papers mainly explored consumer perceptions in Europe (mainly UK, but also Spain, the Netherlands, Sweden, Belgium, France and Germany as well as across EU 27), however, due to their particular relevance to the topic three papers from America (two from US and one from South America) were also reviewed.

Key topics explored by papers included:

- Attitudes of people/consumers towards GM (for example, acceptance, response, perceptions including of risks and gains related to GM, ethical issues).
- Awareness of people/consumers about GM foods.
- Elements/factors that might impact people's/consumers' attitudes or behaviours (for example, scientific literacy, information and product labelling, policy context).

Brief explanation of what the technology is

Drawing on the definition in EU Directive 2001/18, Mallinson et al. (2018; p.1145) define genetically modified organisms as 'organisms with the exception of human beings, in which the genetic material has been altered in a way that does not occur naturally by mating and/or natural re-combination'.

'GM foods are derived from plants, animals or microorganisms with artificially modified genetic material—deoxyribonucleic acid (DNA), for example,, by introduction of a gene from other organisms (viruses, bacteria, other plants and animals and even humans (Popek and Halagarda, 2017; p.325)'. At present, the modifications are predominantly applied in plants, to improve their resistance to disease and/or tolerance to herbicides (Domingo, 2016 cited in Popek and Halagarda, 2017).

Bongoni (2015, p.628) describe GM crops as 'a promising development of science addressing urgent global issues, in the sense that they present the potential to deliver higher yielding foods in a sustainable manner.' The same paper summarises potential benefits that genetically modified foods can offer including:

- 'Agricultural productivity, increased disease and drought-tolerant varieties which mitigate harvest failure.
- Higher yield (food) with lesser utilisation of land, water and other natural resources.
- Decreased need for artificial fertilisers.
- Extended shelf-life of perishables and reducing food wastage.
- Elimination of food allergens.
- Improvement of nutritional quality, for example, golden rice (McLean, 2012)' (cited in Bongoni, 2015, p.628).

The food and feed products derived from GM organisms that are presently permitted on the EU market include a limited range of commodity crops (i.e. crops that are traded), and various processing aids, such as enzymes used during food processing, produced by GM microorganisms within contained facilities.[17] Numerous experimental GM animals with characteristics that are useful for agricultural and food productivity, disease resistance or food quality are in an advanced stage of development and may enter the market outside the EU (Frewer et al. 2013).

SRQ1 What are the public's views on the technology?

The general conclusion in the literature reviewed is that the public views GM food negatively, with low levels of acceptance, especially for GM animals. A review by O' Keefe et al. (2016) of studies and publications on public understanding and perceptions of GM foods identified the following key issues for consumers: 'unnaturalness'; unknown risks; lack of perceived benefits; potential 'unavoidability'; health implications; the motivations of those promoting the technology; and a sense of fatalism over the expansion of GM food (Grove-White et al., 1997; Nelson, 2001; Shaw, 2002; Pidgeon et al.,2005; Tobler et al., 2011 cited in O'Keefe et al. 2016). Hudson et al. (2015) analysed the 2010 Eurobarometer survey and found that overall approval of GM foods depends upon the relative risks and gains, and on perceptions of naturalness and environmental impact of the technology.

A survey of 3,340 people in the UK conducted in 2016 by Mallinson et al. (2018) explored attitudes to GM technology across five areas: trust; GM technology concerns; perceptions of risk and benefits of GM technology; attitudes towards different GM technology applications; and acceptance of GM food including willingness to consume it. They concluded that 'UK consumers as a whole appear fairly ambivalent about GM-food' (Mallinson et al., 2018; p.1158), with overall 54.7% of respondents being open to GM food. However, the analysis identified 'substantial differences in acceptance between different consumer groups (see SRQ4 below).

A study performed by Popek and Halagarda (2017) using a face-to-face survey with 976 randomly selected individuals, to investigate and compare consumer opinions and attitudes regarding GM foods in two relatively culturally diverse cities London (UK) and Warsaw (Poland) showed that only 19.83% of respondents believe that genetic modification regarding food products will bring real benefits, while the views of 27.69% of survey respondents were negative. Over a half (52.48%) did not know what to think about the issue of GM foods. Benefits of GM food identified by respondents included enhanced shelf-life and resistance to extreme climatic conditions as well as (to a lesser extent) reduction in the use of food additives and resistance of plants to bacteria, viruses, and pests. The main concerns included unpredictable consequences of DNA modification, production of species-specific toxins and food allergenicity. The study concluded there were no statistically significant differences observed between the opinions of Polish and British

[17] https://webgate.ec.europa.eu/dyna/gm_register/index_en.cfm

respondents, with the exception of enhanced shelf-life in terms of perceived benefits which was mentioned significantly more frequently by respondents in Warsaw (Popek and Halagarda, 2017, p.328).

Cole et al. (2015) summarise the main conclusions of the literature on consumer perceptions of GM animals for food production, finding that perceptions or attitudes towards GM animals for food are generally more negative than views of GM plants or other less advanced organisms, and that high levels of risk perception in Europe have led to 'consumer rejection' of GM animals in food production.

This was also reflected in a study by Frewer et al. (2013) using a systematic review of 42 English language peer reviewed papers, looking at attitudes towards genetically modified animals in food production. In relation to food products derived from GM animals consumer concerns are not limited to consumption (as is the case for GM plants), but also encompass the use of GM animals in processing of foods and associated ethical concerns (for example, related to animal welfare), which may clarify negative consumer views towards animals in food production. Cole et al. (2015) note that non-food applications of GM animals (such as for pharmaceutical production or as human or animal disease models) 'raise few societal objections' as long as animal welfare standards and safety assessment are addressed.

The idea of GM food labelling was also investigated in this study, showing that people surveyed mainly supported (68.1%) obligatory labelling of GM foods, while 15.5% were against it and for 16.4% of the respondents labelling of GM food products was irrelevant. The respondents indicating negative views toward GM foods showed considerably more support for the idea of GM food products labelling (78.57%) than those with positive attitudes regarding genetic modifications in food (46.15%) (Popek and Halagarda, 2017). The study therefore concluded that there is a need for consumer education and information, however Popek and Halagarda also referred to an earlier study by Scholderer and Frewer (2003) involving consumers from Denmark, Germany, Italy and the UK which showed that no information strategies (for example, labelling) caused an attitude change, on the contrary the product choices were influenced negatively by the provision of information. This finding is supported by a 2016 study in Germany (Wuepper et al., 2018) which used a survey of bakery customers (415 responses) to explore attitudes to GM bread. This found that providing information on GM food had a slightly negative effect on openness to the technology, expressed through willingness to pay (people became slightly more opposed). Similarly, Popek and Halagarda (2017) concluded that understanding the concept of GM technology did not influence attitudes toward GM foods.

SRQ2 How do views differ depending on the type of technology?

The main comparisons made in the literature are between views on GM plants compared to GM animals (Frewer et al., 2013; Coles et al., 2015), and between transgenesis (transfer of genetic material between different species) and cisgenesis (transfer of genetic material within the same species).

Frewer et al. (2013) and Coles et al. (2015) find that the attitudes to GM plants and non-specific GM technology applications are more positive in comparison to GM animal food products. Frewer et al. (2014) reviewed seventy articles in a meta-analysis and found that public rejection of GM animals, in particular those utilised in the agri-food sector, is greater than that associated with GM plants, independent of the region or country where public opinion data is collected. The views seem to be based on the perceptions of risk, benefit, ethical concerns and unnaturalness. In terms of GM animals applied to food production and pharmaceutical and/or medical applications, the authors reflect on a lack of comparative data regarding relative acceptance. However, they state that ‘it is widely assumed that the same pattern of consumer acceptance of food and medical applications as is associated with other GM organisms (such as plants and micro-organisms) will prevail’ (Frewer, Coles et al., 2014; p.1305).

There also appears to be more support for cisgenics than transgenesis. Based on the Eurobarometer 2010 survey data, cisgenic production of apples receives higher support (55%) than transgenic apples (33%), with the former attracting majority support in 24 EU countries. (Gaskell, et al., 2011; Hudson et al., 2015). In the same study based on responses to the Eurobarometer survey 2010 Gaskell et al. (2011) found that cloning of animals for food evokes similar concerns as GM technology and has even less support.

One study by the O’Keefe et al. (2015), using six focus groups with a total of 40 participants in UK in late 2011 and early 2012, reflected on the differences in people’s attitudes towards GM foods and lab meat, revealing that the views associated with GM food are more negative. While the focus groups recognised the potential benefits of the technology, they had negative perceptions of GM foods drawing on their knowledge and uncertainties (for example, health implications) that have been well documented in the media. Lab meat, on the other hand, a new technology that is not currently in the food supply chain, was seen as possibly fitting with current meanings of value (for example, rising food prices making meat too expensive for some) and health; notably, potential advantages were expressed in relation to previous food scares and a more ‘scientific’ approach to meat production. The authors however, recognise that as the lab meat technology develops and draws more public attention and media coverage the views are likely to change.

Coles et al. (2015) considered the perspectives of different stakeholder groups (for example, farmers, manufacturers, consumers) regarding the acceptability of genomic technologies compared to GM technology, specifically in the case of animal production systems. They noted that genomics may avoid many of the disadvantages and consumer perceptions associated with GM technology and is therefore ‘likely to prove a more publicly acceptable route than is GM for the development of healthier and more productive animals’ (Coles et al., 2015 p.231).

SRQ3 What shapes the public’s views?

The short review shows that there are many factors that influence the public’s perceptions of GM foods including: trust in research and institutions (Bongoni, 2016; Frewer, Coles et al., 2014) scepticism (McPhetres et al., 2019); knowledge, information and media (McPhetres et al., 2019; O’Keefe et al., 2016; Bongoni, 2016); education; gender; age; living environment (for example, rural vs. city) (Popek and Halagarda, 2017); risk perception (Bongoni, 2016; Frewer et al., 2014) and material benefits (Bongoni, 2016; Popek and Halagarda, 2017). Citing Frewer et al. (2013) Coles at al. (2015) note that there is ‘a feeling amongst some consumers that because it is ‘‘unnatural’’, GM technology should not be utilised in developing or improving animal species, particularly within the food chain’. Further, Coles et al. (2015, p.237) state that for some individuals ‘this will arise from deeply held religious convictions that GM technology is somehow ‘‘interfering’’ with creation’. Other factors that shape people’s views identified by Coles et al. (2015) include concerns about risk as science does not adequately understand genetics and that there are possible unseen, unintended and potentially irreversible impacts of genetic manipulation that would not occur naturally.

The 2016 survey in the UK (Mallinson et al., 2018) concluded that decision making about GM food is founded on a mixture of rational and affective (emotional) responses. They found that belief in the ‘sanctity of food’ had the strongest impact on acceptance of GM food. Sanctity of food included beliefs that extolled purity, naturalness and integrity in food, as realised by avoidance of processed food and additives, rejection of artificially flavoured food and pesticide use, and support for organic food. They also found that ‘food neophobia’, which is a measure of mistrust of new and different foods showed a negative relationship with acceptance of GM food. Mallinson et al. (2018) conclude that ‘emotional dislike’ of GM food has a strong inverse relationship with acceptance and was found to explain more than 50% of the variance in responses.

Mallinson et al. (2018, p.1152) note that the public’s views are ‘underpinned by a public discourse about food that demonises the synthetic and the new and reveres the natural and the traditional’.

Reviews by Bongoni (2016), Frewer et al. (2014) and O’Keefe et al. (2016) found that trust in institutions and individuals dealing with assessing and regulating GM, as well as information and knowledge about GM foods are key factors determining acceptance of GM foods. Trust in information sources will be determined by socio-cultural and historical contexts (Frewer, Coles et al., 2014). Europe focused research suggests that information about GM technology provided by research institutes and environmental groups tends to be highly trusted, followed by that provided by political organisations and then industry (Savadori et al., 2004 cited in Frewer, Coles et al., 2014).

Based on the Eurobarometer 2010 survey, Gaskell et al. (2011) note that public concerns about safety are paramount in shaping their views of GM foods. Other factors include an absence of benefits (to the consumer) and a sense of unnaturalness.

A study involving UK consumers showed that when knowledge on GM foods was shared, consumers' trust in organisations involved in research and development (R&D) of GM foods was increased, and transparency and openness of R&D outcomes to public critique also contributed to consumers' trust as well as eased their decision-making process in relation to GM foods (Frewer et al., 2004 cited in Bongoni, 2016). However, McPhetres et al. (2019) argue that scientific knowledge and knowledge specific to GM technology may be more important for GM attitudes, as negative GM attitudes are strongest in those with the least knowledge (Fernbach, Light, Scott, Inbar & Rozin, 2019 cited in McPhetres et al., 2019) whilst increased lay knowledge about technological innovations is likely to be associated with more positive views about the applications of these novelties (Li et al., 2004, but see Hilgartner, 1990 cited in Frewer, Coles et al., 2014). However, the study of attitudes to GM bread in a bakery in Germany by Wuepper et al. (2018) (see SRQ1) found that providing information on GM food made people slightly less willing to pay for the food.

McPhetres et al. (2019) also state that other research (for example, Cuite et al., 2005) has shown that knowledge about risk-related aspects of GM technology are better predictors of attitudes. Related to knowledge education also influences attitudes to GM foods (Frewer, Coles et al., 2014). As noted above, the media and wider public discourse also plays an important role in providing consumers with information as well as shaping their views (O'Keefe et al., 2016; Bongoni, 2016; Mallinson, et al., 2018).

Another factor affecting attitudes towards GM foods is scepticism. As summarised by McPhetres et al. (2019, p.22) from various academic papers (for example, Blancke et al., 2015; Dar-Nimrod and Heine, 2011; Heine, 2017; Kronberger et al., 2014; Rozin et al., 2009; Scott and Rozin, 2017) sources of scepticism might be: 'incorrect intuitions about how the world works (for example, a reliance on intuitive conceptions about the natural world may make biotechnology difficult to understand), folk-beliefs about genetic essentialism may lead to aversion towards GM technology, and intuitive preferences for ‘naturalness’ (may make GM foods seem less safe and less attractive).’

Frewer et al. (2014, p.1303) state that ‘underlying risk perceptions inform consumer attitudes’. Bongoni (2016) also mentions ‘uncertainty avoidance and health’ meaning that consumers avoid any unforeseen and unspecified risks of consumption of GM foods, as these risks create anxiety related to uncertain future. As explained, most Europeans tend to avoid uncertainty thus avoiding GM foods. However, Bongoni (2016) also explains that material benefits and risk perceptions related to GM food products play contradictory roles as people tend to ignore the risks due to material benefits and that price is of the utmost importance (Twardowski & Małyska, 2015 cited in Bongoni, 2016).

SRQ4 Do different types of people hold different views?

The views on GM foods seem to differ across cultures, for example Europeans appear to be less accepting of GM foods in comparison to Asian and US consumers (Frewer et al., 2013). Bongoni (2016) makes a comparison between Europeans and Asians looking at five factors that determine acceptance of GM foods across cultures. The study states that Europeans are generally very much against the consumption of GM foods (for example, they believe they are risky, not useful, and should not be encouraged) while Asians are influenced by encouraging attitude of developing countries towards scientific development and innovation and therefore the GM of foods also receives positive support. Coles et al. (2015) note that in Europe consumer rejection of GM animals in food production results from high levels of risk perception. This contrasts with North America and Asia where concerns focus more on moral and ethical issues.

Looking across countries within Europe there are different views on GM foods. Poland is one of nine EU countries that informed the European Commission of its intention to prohibit genetically modified organism (GMO) cultivation and even the marketing of GM foods is restricted in Poland (Bongoni, 2016 cited in Popek and Halagarda, 2017). On the other hand the UK is a leading centre for biotechnology in Europe with English government supporting GMO trials and considering the biotechnology sector as one of the crucial national strengths contributing to UK economic development (Cocklin et al.,2008 cited in Popek and Halagarda, 2017).

A range of other individual characteristics influences views of GM foods, including education and up-bringing, gender, living environment (urban, rural), age, religion and dietary identity (for example, vegetarian).

Gaskell et al. (2011), Hudson et al. (2015), Popek and Halagarda (2017) and Mallinson et al. (2018) all identify scientific education and up-bringing as important factors in people's views on GM technology and foods. Gaskell et al. (2011) find that being socialised in a scientific family or having a university education in science is associated with higher levels of support for GM food (although still less than half of this group support GM food). Hudson et al. (2015) analysed the 2010 Eurobarometer survey and their analysis shows that having studied science, or having parents who studied science is also a factor in levels of approval for transgenesis. Among all survey respondents overall approval for transgenesis was 31.4%, while for respondents who studied science it was 38.2%, and for respondents with a mother or father who studied science the approval was higher still, 43.7% and 43.2% respectively. However support is still below 50% in all cases for transgenesis. Similar to previous studies, a 2016 survey in the UK (Mallinson et al., 2018) found that household income and having a scientific education are positively associated with GM food acceptance, although Mallinson et al. (2018) found that general education was not associated with acceptance.

Popek and Halagarda (2017) found that gender (for example, women having more emotional attitude towards food and nutrition)**,** and age (for example, people aged 41-55 being most positive and people aged 26-40 being most reluctant to accept GM foods), also affect attitudes towards GM foods. The environment people live in also seems to play a part. However, while Popek and Halagarda (2017) imply that in comparison to city dwellers, people living in rural areas were keener to buy GM foods, Hudson et al. (2015) found the opposite. Hudson et al. (2015) also identify that gender is a factor in support of cisgenic and transgenic technologies, with men showing higher support than women. A survey in the UK in 2016 (Mallinson et al., 2018) also showed that gender is a factor in acceptance of GM food, with men more likely to accept it than women. Mallinson et al. (2018) clustered responses, and their analysis showed that 'science-philes' had the most positive attitude to GM foods, and this group was weighted towards white men (62.7% of the cluster). In the same analysis, the cluster 'cautious greens' were least accepting of GM food, and was weighted towards women (65.5%) as well as having the highest proportion of black and minority ethnic respondents.

Based on Eurobarometer data (Hudson et al., 2015), age is a significant factor in approval of transgenesis: as people age they tend to become less favourable to GM technology. This differs from the consideration of naturalness of cisgenesis (which is the only variable for which age is significant for cisgenesis), with people becoming more likely to accept the technology as natural as they age (up until approximately 62 years old). A later survey by Mallinson et al. (2018) carried out in 2016 in the UK also found that young adults (18-24) had greater levels of acceptance of GM food than older adults.

The analysis by Hudson et al. (2015) found that religion is also a factor, with Muslim (40.6%) and Catholic (53.7%) respondents having lower levels of approval of cisgenesis compared to people stating no religion (60.4%). The difference is less marked in relation to transgenesis, although approval is lower among religious people than those with no religion.

Finally dietary identity was a factor in acceptance in the 2016 UK survey by Mallinson et al. (2018), with non-vegetarians being more accepting than other groups.

SRQ5 How do views affect behaviour such as food choices?

Popek and Halagarda (2017) mention a study by Gaskell et al. (2010), which shows that 61% of Europeans do not support GM food products. However, as the authors further explain, when making their everyday purchasing decisions they still tend to buy foods containing GMOs, despite stating reluctance in surveys or questionnaires (Popek and Halagarda, 2017). The literature states that price seems to be of great importance when making purchasing decisions (Twardowski & Małyska, 2015 cited in Popek and Halagarda, 2017). Popek and Halagarda (2017) mention a study by Siegrist (2008) which has proven that the majority of British buyers would purchase a GM food if it was available at a certain price.

SRQ6 How have views changed over time?

A review study by Frewer et al. (2013) shows that data collection in the area of public views and attitudes to GM applied to food manufacturing peaked in 2003, and has declined since. The results of the study further indicate that opinions regarding both risks as well as benefits related to all aspects of GM agri-food application have been increasing with time, regardless of whether animals or other GM applications are the 'target' of the application (Frewer et al., 2013).

Thus, unlike in the build up to the 2009 report (FSA, 2009), research into public attitudes to GM does not seem to be as active, as other emerging food technologies have arisen since. However, the short review indicates that in the last decade the perceptions and attitudes towards GM foods have still be studied and GM technology has also remained an important media topic as one of the first biotechnology applications to enter the food market.

Looking across more recent reviews and empirical research the general picture appears largely similar to that presented in 2009. In the UK a recent survey (Mallinson et al., 2018; p.1158) concluded that consumers were fairly ambivalent towards GM foods. 54.7% of respondents were open to GM food, which appears to show slightly higher support than a study conducted in 2008 (IGD, 2008, cited in FSA, 2009) which found that 52% of respondents neither supported nor opposed GM food. Mallinson et al., (2018) however caution that the way this personal acceptance is recorded and reported differs across surveys so they are not directly comparable. They also note that some surveys have used a single question to measure acceptance, 'which may invite a biased response (Mallinson et al., 2018; p.1149)'.

There is some evidence that in some European countries the negative views are increasing. For example in Poland in 1999, about a third of Polish citizens opposed the use of biotechnology methods in food production, whereas in 2010 almost 60% opposed them and at the same time the number of people supporting GM foods declined from 47% to less than 30% (Twardowski & Małyska, 2012 cited in Popek and Halagarda, 2017).

Gaskell et al. (2011; p.114) based on the 2010 Eurobarometer survey conclude that GM food 'is still the black sheep of biotech' as the survey shows that support for GM across many EU member states is declining, with on average opponents outnumbering supporters by about 3 to 1 and no EU member state having a majority of support for GM food.

SRQ7 What are the gaps in current research?

Frewer et al. (2013; p.149) state that 'continued research is required to track changes in acceptance over time, and between different geographical and/or cultural regions, given the geographical and temporal diversity of attitudes, although this should be designed in such a way as to facilitate prospective analysis. Due consideration should be given to factors which may perturb general temporal trends (for example, the introduction of a controversial application, or one which is perceived as being particularly beneficial by the public).'

Conclusions/summary

- Issues related to GM foods include; 'unnaturalness', unknown risks, lack of perceived benefits, potential 'unavoidability' of risks, health implications (for example, unpredictable consequences of DNA modification, production of species-specific toxins and food allergenicity), the motivations of those promoting the technology and a sense of fatalism over the expansion of GM food (Grove-White et al., 1997; Nelson, 2001; Shaw, 2002; Pidgeon et al.,2005; Tobler et al.,2011 cited in O'Keefe et al. 2016; Popek and Halagarda, 2017).
- Attitudes towards animal based GM foods are in comparison to plant based GM foods more negative (Frewer et al., 2013; Frewer, Coles et al., 2014).

- GM foods are still seen as ‘the black sheep of biotech (Gaskell et al., 2011; p.114)’ as a result of the very bad publicity the technology has received over the years.
- A number of factors have been shown to influence the public’s perceptions of GM foods including: trust in research and institutions (Bongoni, 2016; Frewer et al., 2014) scepticism (McPhetres et al. 2019); knowledge, information and media (McPhetres et al. 2019; O’Keefe et al., 2016; Bongoni, 2016); education; gender; age; living environment (for example, rural vs. city) (Popek and Halagarda, 2017); risk perception (Bongoni, 2016; Frewer et al., 2014) and material benefits (Bongoni, 2016; Popek and Halagarda, 2017).
- Views on GM foods differ across global cultures (for example, Asians seem to be more acceptant in comparison to Europeans; Bongoni, 2016); between European countries (for example, UK government is favourable to GM technology while Poland holds very negative views; Popek and Halagarda 2017); and among people (for example, scientists and more educated and knowledgeable people hold more positive views towards GM foods; Popek and Halagarda 2017).
- Some research shows that although Europeans generally do not support GM food they still buy it and price seems to play a crucial role when it comes to purchasing decisions (Twardowski & Małyska, 2015 cited in Popek and Halagarda, 2017).
- There is evidence that perceptions of both risks as well as benefits related to all aspects of GM agri-food application have been increasing with time, regardless of whether animals or other organisms are the ‘target’ of the application (Frewer et al., 2013).
- The current gaps in research include: continued research to track changes in acceptance over time and between different geographical and/or cultural regions, including consideration of factors which may perturb general temporal trends (for example, the introduction of a controversial application, or one which is perceived as being particularly beneficial by the public) (Frewer et al. (2013). The review also indicated that there has been more research on attitudes to plant-based GM foods in comparison to animal-based applications

Nanotechnology applied to foods

Key findings

- Consumer awareness and understanding of nanotechnologies applied to food is relatively low.
- No consensus exists among the reviewed literature about what the publics’ views are on nanotechnology in food.

Although some evidence suggests that consumer attitudes are generally positive, other studies report a level of ambivalence and even reluctance towards food applications of nanotechnology.

- Attitudes towards nanotechnology in food are generally more positive than attitudes towards GM food.
- In comparison to the 2009 FSA review of consumer attitudes towards emerging food technologies that reported overall positive attitudes towards nanotechnology in food, this review found evidence to suggest ambivalence and even reluctance among consumers towards food nanotechnology.

Overview of literature

The review was based on 10 papers comprising five review papers and five empirical papers. All the empirical studies used quantitative survey data and explored consumer perceptions in several European countries including the UK, France, Germany, and across Europe as a whole. One study looked at US consumers. Other background documents have also been drawn on, for example, the House of Lords Science and Technology Committee's report on Nanotechnology in Food, 2009-2010.

Key topics explored by the papers included:

- How the provision of risk and benefit information influences attitudes to nanotechnology applied to food (Bennett and Radford, 2017; Fischer et al., 2013).
- Lessons about public attitudes from the debate on Genetically Modified Foods (Frewer, Gupta et al., 2014).
- Factors shaping consumer perception and attitudes to emerging products (Kuzma, 2017).
- Governance and regulatory frameworks for nanotechnology in food (Santeramo et al., 2018).

Brief explanation of the technology

Nanotechnology involves engineering very tiny particles: a nanometre (nm) is one thousand millionth of a metre. The properties of nanoparticles can differ substantially from the same materials in their larger form. With an understanding of the properties of nanoparticles in specific materials, they can be used to control or alter the operation of structures, devices and systems (House of Lords Science and Technology Committee, 2010).

Nanotechnology for food is an approach involving the engineering of nanoparticles for a variety of applications in the food sector to provide benefits including sensory improvements (for example, to taste or smell), increased absorption of nutrients, stabilisation of bioactive compounds, extended product shelf-life, quality and safety monitoring (Dasgupta et al., 2015; Handford et al., 2014; Pathakoti, Manubolu, & Hwang, 2017; Ranjan et al., 2014; Rossi et al., 2014; all cited in Santeramo et al., 2018).

The difference between nanotechnology and GM is that nanotechnology involves the manipulation of 'matter' and usually applies chemical or structural changes, whereas GM involves the manipulation of living organisms and primarily involved 'genetic' changes to ingredients (Kuzma & Priest, 2010 cited in Yue et al., 2015; Kuzma, 2017). Additionally GM foods already are much more prevalent on the markets compared to foods where nanotechnology has been applied (Zhou et al., 2013 cited in Yue et al., 2015). Finally, GM foods have had higher medial and policy debates compared to foods where nanotechnology has been applied (Yue et al., 2015).

Two main types of nanotechnology food applications are distinguished: 'nano-inside' applications when nanoparticles are incorporated into the food product, and 'nano-outside' applications when nanoparticles are incorporated into food contact materials like packaging (Handford et al., 2014; Pathakoti et al., 2017; cited in Santeramo et al., 2018).

SRQ1 What are the public's views on the technology?

There is a lack of clarity among members of the public as to what nanotechnology is (Bennett and Radford, 2017). One fifth of consumers who participated in a European Union-funded project to investigate how opinion on nanotechnology is shaped and how to inform public debate, had never heard of nanotechnology and less than half of respondents could answer more than half of five questions on a 'nanotechnology knowledge' quiz correctly (NanOpinion, 2014). Furthermore, researchers have reported that media information about nanotechnology in food is severely limited (Dudo et al. 2011 cited in Yue et al., 2015) and that public awareness is low with 62 % of Americans hearing only the term or nothing at all about nanotechnology (Harris, 2012 cited in Yue et al., 2015).

Partly linked to lack of information, studies in a number of different countries have found that public attitudes towards nanotechnology in general and nanotechnology in food in particular are often weak, neutral or somewhat ambivalent and vary between individuals (Fischer et al., 2013; Santeramo et al., 2018).

A literature review by Frewer, Gupta et al. (2014) suggests that, overall, public attitudes towards nanotechnology in foods tend to be somewhat positive, and that the perceived benefits tend to outweigh the perceived risks (Priest & Greenhalgh, 2011; Satterfield, Kandlikar, Beaudrie, Conti, & Harthorn, 2009; Stampfli, Siegrist, & Kastenholz, 2010, all cited in Frewer, Gupta et al., 2014). Findings of the 2010 Eurobarometer on the life sciences showed that, described in the context of common consumer products, three out of five participants support the use of nanotechnology (Gaskell et al., 2011). Safety was the most important consideration, followed by benefits (Gaskell et al., 2011). However it is important to note that these findings don't specifically apply to nanotechnology applied to food.

Alternatively, an empirical study (n=295) of French and German consumers' willingness to pay for food products where nanotechnology had been applied found that many participants were reluctant to accept nanotechnology applications in food products (Bieberstein et al., 2013).

Negative attitudes about GM foods and foods where nanotechnology has been applied have been shown to be positively correlated with a desire for labelling (Yue et al., 2015).

Other research identifies concerns about the potential risks of using nanotechnology to produce food and food products that have been brought up by stakeholder groups:

- The potential for it to contaminate the food with which it came into contact.
- The possibility of migrating into the human body via ingestion.
- Concerns about potential side effects.
- Beliefs that the technology could be misused.
- Food with nanotechnology applied being perceived as an unnatural product. (Conti et al., 2011; Casolani et al., 2015; Kohler and Som, 2008; Becker, 2013; Simons et al., 2009, cited in Gupta et al., 2017).

SRQ2 How do views differ depending on the type of technology?

Attitudes towards different applications of the technology

The literature suggests that the public's views of nanotechnology in food vary depending on the application of the technology. Particular comparisons between nano-inside and nano-outside applications are made. However, evidence on whether acceptance is higher for one type of application is mixed.

For example, findings of a US-based empirical study (n=1131) found that consumers valued the NANODROPS attribute (fortified 'nanodrops' added to canola oil that block cholesterol absorption by the digestive system) positively and higher than the other nano-attributes (NANOAG and NANOPACK where the technology was used in the agricultural process and in the packaging respectively). The authors suggest that this may be because of the explicit benefits this product offered to the consumer (Zhou & Hu 2018)[18].

Alternatively, a number of studies have found that the use of nanotechnology in external application such as packaging foods ('nano-outside') is perceived to be more beneficial than its use in food products ('nano-inside') (Siegrist et al., 2007; Siegrist et al.,2008; cited in Frewer, Gupta et al., 2014; Stampfli et al.,2010, cited in Gupta, 2017; Brown & Kuzma, 2013 cited in Yue et al.,2015). However, similar to findings of Zhou & Hu (2018), Brown & Kuzma (2013) did find that consumers prefer improved food safety and nutritional content over other types of benefits (Brown & Kuzma, 2013 cited in Yue et al., 2015).

Comparisons with other technologies

Nanotechnology use in food production has often been compared with GM foods, but many authors note that the research on attitudes to nanotechnology has been much more limited (Frewer et al.,2002; Pidgeon et al., 2003; Scheufele et al., 2007; all cited in Frewer, Gupta et al., 2014; Yue et al., 2015). Our review indicates that there is still considerably less research on the use of nanotechnology in the food system than on GM foods.

A large scale US survey using choice experiments to compare consumer attitudes to GM and nanotechnology in food found that consumers are willing to pay more to avoid both foods where nanotechnology or GM has been used, but will pay a higher premium to avoid GM foods than foods where nanotechnology is used (Yue et al., 2014 cited in Yue et al., 2015). Similarly, another choice experiment among US consumers (n=1131) comparing willingness to pay for different nanotechnology and GM attributes found that being non-GM significantly increased the value of a product (Zhou & Hu, 2018)[19]. For both technologies, the benefits that were most accepted were safety, nutrition, the environment and taste, in that order. In the case of foods

[18] Zhou & Hu (2018) used a choice experiment to investigate consumers' valuation of canola oil (one of the most used cooking oil, being number one in Canada and Japan, and number two in Mexico and the US) products with different nano-attributes. The three types of nano-attributes included NANOAG (nanotechnology used in the cultivation and production of canola seeds), NANOPACK (nanotechnology used in the packaging), and NANODROPS (fortified 'nanodrops' added to the canola oil that block cholesterol absorption by the digestive system). Consumers did not distinguish between NANOAG and NANOPACK attributes and were willing to pay less per bottle for each of these attributes.

[19] Consumers were willing to pay more for a typical bottle of canola oil with the dummy variable 'NONGMO' attribute (Zhou & Hu, 2018).

with nanotechnology, but not GM, certain benefits of better nutrition or food safety were considered to be greater than the technology's disbenefits (Kuzma, 2017).

Yue et al. (2015) found a number of differences exist between what shapes consumers' perceptions of nanotechnology in food and GM food. For example, results of the study showed that consumers' trust in government did not affect their support for policies of restricting nanotechnology in food, but it did positively affect their support for policies restricting GM. The authors suggest that this could be due to greater consumer awareness of the risks associated with GM food caused by higher profile media debates in the past decades (Yue et al., 2015). It is also suggested that, because of the high media exposure of GM, consumers are more eager for policies restricting GM food than foods with nanotechnology applied, suggesting some ambivalence toward nanotechnology in food and government regulatory policy (Yue et al., 2015).

Yue et al. (2015) also demonstrate that the relationship between preference for labelling and willingness to buy (WTB) is different for GM food and food with nanotechnology (see SRQ5 How do views affect behaviour such as food choices?).

Frewer, Gupta et al. (2014) suggest that the nanotech industry and regulators have learnt lessons from the experience of GM. Consumer rejection of first generation GM foods was found to be directly linked to a perception that the technology offered no personal and societal benefits of relevance to consumers. Learning from this experience has resulted in increased acceptance of agrifood applications by consumers.

However, other evidence studies suggest that experts have continued to interpret the negative consumer response to GM foods as the standard consumer response to new technologies and have failed to recognise changes in the socio-political context such as regulation designed to increase consumer protection (Frewer et al., 2011 cited in Gupta et al., 2017). Consumers today make decisions about the acceptability of the use of technologies in the food industry based on multiple factors (see SRQ3 What shapes the public's views?below) and a narrow focus on parallels with GM foods may be misleading (Gupta et al., 2017).

SRQ3 What shapes the public's views?

The factors which drive consumer acceptance may differ from those recognised by experts (Gupta et al., 2013 cited in Frewer, Gupta et al., 2014). The literature identifies a range of factors which contribute to positive public views of the use of nanotechnology in foods:

- Perception of health and nutritional benefits especially for the poor and elderly (Kuzma, 2017, Santeramo et al., 2018).

- Clarity on responsibilities, for example, for creating, regulating or providing information on the safety of products (Gupta et al., 2017).
- Higher level of trust in the nanotechnology industry (Gupta et al, 2017, Santeramo et al., 2018; Siegrist et al., 2007 cited in Yue et al., 2015) and government regulatory agencies (Yue et al., 2015).
- General attitude towards new technology (neophobia/neophilia) (Santeramo et al., 2018).
- Role of the media in providing information and encouraging interest: 'The public use the importance of information provided by the media as cognitive shortcuts or heuristics in trusting scientists and forming an opinion about nanotechnology.' (Gupta et al., 2017 p.54) and positive framing on nanotechnology in the media (Bieberstein et al., 2013).

Providing information about nanotechnology has been found to influence attitudes of members of the public in different ways. Several studies have looked at the results of providing 'balanced' information about the costs and benefits of nanotechnology applied to foods, indicating that some individuals become more positive, others more negative (Kahan et al., 2009, cited in Frewer, Gupta et al., 2014).

Factors contributing to create or reinforce negative views of nanotechnology in foods include:

- Lack of perceived societal or consumer benefits.
- Perception that there are hidden vested interests on the part of industry and institutions (Gupta et al., 2017).

There was a difference in the literature examined over the significance of the nano-inside' / 'nano-outside' distinction in determining views: studies by Gupta et al. (2012, 2013, both cited in Frewer, Gupta et al., 2014) found that consumers were less concerned about potential physical contact with products than had been assumed by experts. Santeramo et al. (2018) also suggest that this is an important factor, though they do not cite evidence. See SRQ2 How do views differ depending on the type of technology? for more on this.

There is evidence that consumers today make decisions about the acceptability of foods or food production technologies, 'based on a complex interaction of perceptions of risk and benefit associated with specific food choices' (Gupta et al., 2017, p50).

A US study (n=990) found that attitudes towards nanotechnology in foods and GM foods were influenced by trust in government but preference for labelling of these technologies was not (Yue et al., 2015). However, the stronger consumers' support for restrictions on GM and nanotechnology applications in food, the greater preference for labelling. The authors suggest that preference for labelling may therefore be mediated by other factors such as right to know and choose, rather than trust to ensure safety (Yue et al., 2015).

SRQ4 Do different types of people hold different views?

In a US study (n=990), gender and household income appeared to influence attitudes towards both food where nanotechnology has been applied and GM food. Willingness to buy (WTB) and preference for labelling of GM food was also influenced by gender and religiosity, but this was not the case for nanotechnology (Yue et al., 2015). The authors suggest that a lack of experience with food nanotechnology could be a factor in this difference.

Fischer et al. (2013) conducted two experiments on how attitudes to nanotechnology in foods change as a result of the provision of information on risks and benefits. They found that although on average attitudes did not change, the majority of the small proportion of individuals who became more positive were male and more highly educated. This is supported by other research (Conti et al., 2011, Simons et al., 2009[20], both cited in Gupta et al., 2017).

Analysis of the results of the 2010 Eurobarometer on the life sciences showed that having been socialised in a scientific family or having a university education in science is associated with greater technological optimism, more confidence in regulation based on scientific delegation, and a greater willingness to encourage the development of both nanotechnology and GM foods (Gaskell et al., 2011).

A study of French (n=152) and German (n=143) consumers revealed that French consumers were less willing to accept nano-packaging than nano-fortification with vitamins, whereas German consumers were more averse to accepting the nano-fortification than the nano-packaging (Bieberstein et al., 2013). This may be due to differences in prior beliefs and familiarity linked to long-term country-specific traditions, or differing roles of the state in consumer protection (Bieberstein et al., 2013).

SRQ5 How do views affect behaviour such as food choices?

A US empirical study (n=990) by Yue et al. (2015) revealed that consumer purchase intention of GM food or nano-food is significantly dependent on their attitudes towards the two technologies. In particular, views on risks and benefits were found to influence WTB. Moreover consumer trust in government regulation of the technology positively influences consumer attitudes towards the food technology. Therefore this supports the existence of an indirect positive causal relationship

[20] J. Simons, R. Zimmer, C. Vierboom, I. Härlen, R. Hertel and G. F. Böl, *J. Nanopart. Res.*, 2009, **11**, 555–1571.

between trust in government and WTB GM or food with nanotechnology applied (Yue et al., 2015).

Furthermore, a relationship between consumer preference for labelling of nano-ingredients and WTB foods that have had nanotechnology applied exists: the more consumers want labelling, the less they are willing to buy foods with nanotechnology (Yue et al., 2015). This was not the same for GM food where consumer preference for labelling of GM did not significantly affect their willingness to buy GM food (Yue et al., 2015). It is suggested that the tighter coupling of WTB and preference for labelling for nanotechnology in foods could be due to the unfamiliarity (Yue et al., 2015).

SRQ6 How have views changed over time?

According to Bennett & Radford (2017) there has been little change in public knowledge of or attitudes to the use of nanotechnology in foods since 2009. This review found there is still a lack of clarity and understanding among consumers about what nanotechnology is and how it is applied to food. The 2009 FSA review of consumer attitudes towards emerging food technologies found that although awareness of nanotechnologies was low, general attitudes towards them seemed fairly positive (FSA, 2009). Similarly, some of the literature in this review, including a UK study, suggests that attitudes towards nanotechnology in food are somewhat positive (Frewer, Gupta et al., 2014). However, there is no consensus among this reviewed literature. For example, there is other evidence to suggest weak, neutral or ambivalent attitudes (Fischer et al., 2013; Santeramo et al., 2018) or even reluctance towards nanotechnology in food (Bieberstein et al., 2013) (see SRQ1 What are the public's views on the technology?).

Frewer, Gupta et al. (2014), p.213, suggest that 'the relative (lack of) consumer debate associated with consumer acceptance of nanotechnology may relate to changes in cultural values between the mid 1990's, when the first GM agricultural applications were introduced, and the present time, when nanotechnology applied to food production is ready for commercialisation.'

Gupta et al. (2017) suggest that a constant re-evaluation of public views on food nanotechnology is needed because it is unlikely to be static, but rather influenced by external events, including the order in which products are entered onto the market.

SRQ7 What are the gaps in current research?

The main gaps in research on public perceptions of nanotechnology relate to the need for research focusing on specific applications. Frewer, Gupta et al. (2014) propose the following questions:

- Do the applications to the agrifood sector meet a recognised societal or consumer need?
- What similarities with potentially societally controversial aspects of previously applied agrifood technologies can be identified?
- Are additional issues raised over and above those associated with other enabling technologies applied to food production?
- How can benefits and risks be equitably distributed across all stakeholders?
- What needs to be done to fine tune the development and implementation of agrifood applications of nanotechnologies to align with consumer priorities, adoption and commercialisation of specific applications?

Conclusions/summary

- Consumer awareness and understanding of nanotechnologies applied to food is relatively low.
- No consensus exists among the reviewed literature about what the publics' views are on nanotechnology in food. Although one review paper suggests that consumer attitudes are generally positive, other empirical studies report a level of ambivalence and even reluctance towards food nanotechnology.
- Findings of this review suggest that attitudes towards food nanotechnology can vary depending on the nanotechnology application used, particularly between nanotechnology applied in the food or out of the food (applied to the packaging).
- Consumer attitudes towards nanotechnology are often compared with those towards GM foods; however the research on consumer attitudes towards nano-foods is much less extensive. Research also suggests that drawing parallels between food where nanotechnology is applied and GM foods may be misleading.
- Factors influencing consumer attitudes towards nanotechnology in food include perceived risks and benefits, perceptions of safety, trust in the nanotechnology industry and government regulations, information provision, and general attitudes towards new technologies.
- There is evidence to suggest that gender, household income, and education influence attitudes towards nanotechnology in food.
- Public awareness of nanotechnology in food does not seem to have increased since the 2009 FSA review. However from this current review there appears to be less of a consensus in the literature to how consumers view nanotechnology in food, with some evidence to suggest views have become more ambivalent.

Functional food

Key Findings

- It has not been possible to generalise consumer attitudes towards functional foods as a whole, given the range of products included in this category.
- Consumer attitudes towards specific functional food products depend on the perceived necessity of the product, perceived healthiness, and the perceived naturalness of the combination of 'carrier' product and added functional ingredient.
- Overall, this review does not show that consumer attitudes to functional foods have particularly changed since 2009.

Overview of literature

Review based on 11 academic papers comprising three reviews and eight empirical studies. Of the empirical papers five was quantitative, two were qualitative and one was mixed.

Empirical papers explored consumer perceptions in several European countries, including Germany, Ireland, Spain, Turkey, and Poland; and also Australia.

The systematic review paper by Bimbo et al. (2017) studied 42 articles, covering a global geographical range, with Northern Europe, North America and Uruguay being the most investigated. Another systematic review paper by Özen et al. (2014) covered 22 European papers, however only one of the reviewed papers was published after 2009. The final review paper included in this report is a review by Santeramo et al. (2018) that reviews emerging trends in European food, diets and food industry and includes a case study on functional foods as an example of an emerging innovation in the food industry.

Key topics explored by papers included:

- Consumer acceptance of specific functional foods.
- Factors influencing consumer acceptance of functional foods.
- Factors influencing purchasing decision and food choice of functional foods.

Brief explanation of what the technology is

A definition of functional foods used by Kuster-Boluda & Vidal-Capilla (2017) comes from the International Life Sciences Institute. They define functional foods as those that 'include a variety of relevant components to improve health status or reduce the risk (non-prevention) of disease. Those foods also must bring benefits beyond those of basic nutrition. For example, foods that are low in fats and sugars or incorporate fibre, among others, are functional foods. For a food to be classified as functional, its health properties must be supported by scientific evidence' (Kuster-Boluda & Vidal-Capilla, 2017 p.1). A similar definition is given in Santeramo et al. (2018): 'The term 'functional food' is generally used to communicate either that the food may provide health benefits beyond those delivered by traditional nutrients, or that the food has potential in preventing disease or in promoting a better life quality (Griffiths, Abernethy, Schuber, & Williams, 2009).' p.42.

Functional foods include a large number of products. The literature in this review either focuses on consumer attitudes towards a specific functional food (for example, a specific dairy product with a bifidus effect (Barrena & Sanchez, 2010)), categories of functional foods (for example, functional dairy products (Bimbo et al., 2017), vitamin D-fortified products (Sandmann et al., 2015), or enriched processed meats (Shan et al., 2017)) or a whole range of functional foods (for example, Kuster-Boluda & Vidal-Capilla, 2017).

SRQ1 What are the public's views on the technology?

Santeramo et al. (2018) argue that consumer demand for health-enhancing food products, such as functional foods has grown rapidly. However, from this review, it is not possible to generalise consumer attitudes towards functional foods overall since the majority of the reviewed literature focuses on attitudes towards a particular product or in a particular locations. Instead, the majority of the reviewed literature focuses on understanding the underlying factors that shape consumers' perceptions of various functional foods.

In an empirical study (n=1051), Sandmann et al. (2015) aimed to better understand consumer perceptions of vitamin D-fortified foods to investigate how German consumers would react to a large-scale vitamin D-fortification programme. They found that consumer purchase intention for Vitamin D-fortified foods in Germany was much higher than expected and that German consumers showed a high level of acceptance to such products.

Another empirical study (n=486) found that Irish consumers were generally more uncertain than positive about enriched processed meats (Shan et al., 2017). Consumers were not convinced by the benefits of consuming enriched meats, although they recognised the value of such products for already frequent consumers of meat products (Shan et al., 2017). Other recent previous studies had found that consumers hold concerns about the suitability of processed meat as a carrier food for healthy ingredients, the overall health characteristics, and necessity of the final product; but many consumers were open to the product idea if taste, price and shelf-life are not to be significantly compromised (Hung et al., 2016b; Shan et al., 2016; Tobin et al., 2014, cited in Shan et al., 2017).

SRQ2 How do views differ depending on the type of technology?

None of the literature included in this review made comparisons between public views of functional foods and other food technologies. Differences in consumer attitudes towards different functional food products, however, were investigated by several authors.

A systematic review of 42 papers by Bimbo et al. (2017) found that different intrinsic product attributes were important to consumer acceptance of functional dairy products. For example, the carrier product appears to influence consumers' perceptions of healthiness of a product where there is a positive effect when a 'natural' match between carrier product and added bioactive ingredients exists and a negative effect when there is an 'unnatural' match. For example, calcium being added to yoghurt versus omega-3 added to yoghurt (Bimbo et al., 2017).

A similar finding is found by Shan et al. (2017) in that different enriched processed meat products were not equally perceived in terms of healthiness, depending on the base product (Shan et al., 2017). Comminuted meat products (for example, sausage-type products) were perceived as least healthy, while cured whole muscle cuts such as ham products and bacon were perceived as more healthy.

Furthermore, in an empirical study that explored Turkish consumer attitudes to 18 functional foods, Çakiroğlu & Uçar (2018) found that 'kefir' and 'fat-reduced yoghurts' were the most purchased and consumed functional foods among the milk and dairy products. The authors point out that yoghurt and kefir originate in this geographical so these products are already consumed by participants regularly, therefore this might be why these products received high acceptance (Çakiroğlu & Uçar, 2018). Other products found to be purchased and consumed the most by Turkish consumers were 'breakfast cereal' among the cereal products, 'herbal tea' among beverages, and 'cholesterol-free margarine' among the other products (Çakiroğlu & Uçar, 2018).

SRQ3 What shapes the public's views?

The reviewed literature shows a number of consumer-related factors and product-related factors that influence acceptance of and preference for functional foods. Consumer-related characteristics that influence preference for functional foods can be further classified into Personal Factors, Psychological Factors, and Cultural and Social Factors (Kaur & Singh, 2017 cited in Santeramo et al., 2018).

Personal factors influencing attitudes towards functional foods:

- High income and high education level is associated with positive consumer behaviour towards functional foods (Hung, de Kok, & Verbeke, 2016; Hur & Jang, 2015; Jezewska- Zychowicz & Krolak, 2015; Schnettler et al., 2015 all cited in Santeramo et al., 2018).
- Consumption frequency has also been found to increase acceptance (Shan et al., 2017).
- General food choice habits (for example, health, convenience, sensory appeal, natural content, price, and familiarity) were also found to influence acceptance of enriched processed meats (Shan et al., 2017).

Psychological factors include:

- Attitudes towards functional foods (Shan et al., 2017; Kuster-Boldua & Vidal-Capilla, 2017).
- Attitudes towards health and taste (Bimbo et al., 2017).
- Attitudes towards base products (for example, processed meat, particularly perceptions of healthiness (Shan et al., 2017; Bimbo et al., 2017).

Socio-cultural factors include:

- The likelihood of functional food acceptance increases with the presence of an ill family member (Loizou et al., 2013 cited in Santeramo et al., 2018).
- Doctors or dieticians being the source of information (Loizou et al., 2013 cited in Santeramo et al., 2018).
- The presence of children in the household (Bechtold & Abdulai, 2014 cited in Santeramo et al., 2018).

Sandmann et al. (2015) also found that health awareness positively correlated with acceptance of vitamin D-fortified foods among German consumers. However a systematic review by Bimbo et al. (2017) concluded that further research is needed to establish whether diet-health and nutritional knowledge influences acceptance of functional foods as many of the studies they reviewed used non-validated scales to measure this. Furthermore, adopting a healthy lifestyle was not found by Kuster-Boluda & Vidal-Capilla (2017) to positively influence willingness to consume functional foods and they highlight previous studies that have emphasised a negative relationship between healthy lifestyle and willingness to consumer functional foods (Siro, Kapolna, and Lugasi, 2008; Poppe & Kjærnes, 2003 cited in Kuster-Boluda & Vidal-Capilla, 2017).

Results of a consumer survey carried out in 2009 with 500 German consumers further confirm a link between the consumption of functional foods and a passive lifestyle (Goetzke & Spiller, 2014). The study compared understandings of health and health and well-being improving lifestyles of consumers of organic and functional foods. Although consumers of functional food have a similar concept of health and well-being to organic consumers, they differ in ways of achieving this. Consumption of organic foods is associated with an active lifestyle to improve health whereas consumption of functional foods is associated with passive lifestyles to improve health (Goetzke & Spiller, 2014).

Product-related factors that have been found in the reviewed literature to influence consumer acceptance of functional food include:

- Intrinsic product characteristics such as price and flavour (Barrena & Sanchez, 2010), or whether the match between base product and the added ingredient is considered 'natural' (Bimbo et al., 2017). Additionally, some functional ingredients and base products are valued higher than others. Some studies suggest that carrier products may receive greater importance than functional ingredients (Bitzios et al., 2011 cited in Santeramo et al., 2018).
- Extrinsic product characteristics such as labelled nutritional and health information and brand were also found by Barrena & Sanchez (2010) to have an effect. However, in a review, Bimbo et al. (2017) found conflicting results in the literature for labelled nutrition and health claims.

SRQ4 Do different types of people hold different views?

In a systematic review of 42 articles, Bimbo et al. (2017) conclude that gender and age play an important role in explaining differences in acceptance of different combinations of carriers and added ingredients of functional dairy products. They found female consumers more willing to consume yoghurt enriched with calcium, fibre and probiotics, and also low-fat dairy products. Willingness to purchase and consume functional dairy products also increases with age (Bimbo et al., 2017). This result differs from previous reviews by Ozen et al. (2012 and 2014) (cited in Bimbo et al., 2017). These authors concluded that it was not possible to identify how gender, age, education level and socio-economic factors influence consumption of functional foods (Ozen et al., 2012, cited in Bimbo et al., 2017) and further failed to identify gender differences in consumption of nutrition-modified and functional foods in Europe, although pointed to differences in functional food consumption across different European countries, with higher consumption in Northern Europe (Ozen et al., 2014). In their review of 22 European papers, Ozen et al. (2014) also found that a high percentage of adolescents in the European Mediterranean countries (Spain, Cyprus, but not Italy) consumed functional foods. This therefore contrasts with the results of this later review by Bimbo et al. (2017).

A quantitative empirical study of Polish consumers (n=200, 137 women and 63 men, aged 18-60 years) also revealed that there are significant differences between how different groups of consumers evaluate the significance of different variables in the selection of functional foods (Kraus et al., 2017). It was found that women, older people (35-60 years), and those with a university education attribute the greatest significance to naturalness, nutritional value, freshness, food safety, and quality guarantee[21]. Gender differences in the importance of the functional components were also discovered: they were significantly more important to women than men. Kraus et al. (2017) also found differences in preferences for different base/carrier products: young men preferred meat products, whereas women and older men preferred cereal products. Purchase motivations also differed with age and gender, for example compared to women and older men, young men attached less importance to functional and psychological consequences of purchasing functional food (Kraus et al., 2017).

Barrena & Sanchez (2010) found that family structure had an effect on cognitive purchasing decisions of functional dairy products with a bifidus effect. The study (n=60) looked at two groups (households with children and households without children) and found that the two groups both displayed interest in certain functional benefits of purchasing such a product, but differed in respect of other functional benefits (Barrena & Sanchez, 2010). For example, consumers from both households with children and without children were interested in concrete attributes such as price and reported the product to be ‘good value for money’. Only consumers with children in their household, however, were interested in the abstract attributes ‘low in cholesterol’, ‘health benefit effect’, and ‘quality’ (Barrena & Sanchez, 2010).

An Australian empirical study (n=493) found that pregnant women and women contemplating pregnancy expressed a reluctance to use probiotics (Ramsay et al., 2014). The authors suggest that this is due to a lack of understanding of the safety and benefits of probiotics foods during pregnancy (Ramsay et al., 2014). In contrast, women not contemplating pregnancy were most likely to consume probiotics concurrently of consuming vitamin supplements.

SRQ5 How do views affect behaviour such as food choices?

Attitude and health perceptions of processed meat, as well as frequency of processed meat consumption, were found to be better predictors of Irish consumers’ purchase intention towards enriched processed meat than general food choice motivations and socio-demographic factors (Shan et al., 2017). Shan et al. (2017) conclude that attitude was the main driver of intention to purchase enriched processed meat which complements previous literature that has suggested that a positive attitude towards functional foods is a significant predictor of the purchase intention and overall spending on this type of food (Carrillo et al., 2013; Patch et al., 2005 cited in Shan et al., 2017). The fact that perceptions of healthiness was also important for purchase intention suggests that primary purchasers of enriched

[21] Perceived quality attributes assessed in the questionnaire were organoleptic (sensory)attributes and attributes of packaging and labelling.

process meats are likely to be consumers who are positive about health characteristics of processed meats and positive about healthy ingredient enrichment (Shan et al., 2017). Kuster-Boluda & Vidal-Capilla (2017) also showed that attitude influences consumers' willingness to consume functional foods, confirming previous studies by Urala and Lahteenmaki (2007) and Chen (2011) cited in Kuster-Boluda & Vidal-Capilla (2017).

Alternatively, Barrena & Sanchez (2010) investigated the role of family structure on purchase decision of a functional dairy product (dairy product with bifidus effect). They found that there were similarities and differences in the factors affecting the two groups' (households with children and households without children) decision to purchase such a product. In general, both groups adopted this functional food product for hedonic attributes, specifically enjoyment and pleasure factors, and its nutritional value. Consumers from households with children placed particular importance to factors relating to the health and benefit effects of this product, and to its quality. Consumers from households without children attached importance to ease of consumption and time-saving factors in purchasing decisions (Barrena & Sanchez, 2010).

A Polish study (n=200) found that different sociodemographic groups demonstrate significant differences in what influences their decision to purchase functional foods (Kraus et al., 2017), also see SRQ4.

SRQ6 How have views changed over time?

None of the reviewed literature tracks attitudes to functional foods over time, however according to Bimbo et al (2017), consumer demand for functional foods and nutrition-modified foods (for example, foods with added fibre) has increased rapidly over the recent decade. According to Santeramo et al (2018), the value of the global market for functional foods was reported at $168 billion for 2013 and forecasts more than $300 billion for 2020.

Resembling the findings of the 2009 FSA review of consumer attitudes to emerging food technologies, the literature on consumer attitudes towards functional foods still generally focuses on particular products in particular locations (for example, acceptance of enriched processed meat in Germany), which makes it difficult to draw general conclusions. Overall, however, functional foods still do not tend to elicit particularly negative or hostile public attitudes, as was the case in 2009 (FSA, 2009).

Barrena & Sanchez (2010) highlight previous findings that suggest considerable growth in the market for functional or enriched products, with estimated growth ratios of between 15 and 20% in Europe and the US (Teratanavat & Hooker, 2006 cited in

Barrena & Sanchez, 2010). However these claims are out-dated and the reference used pre-dates the last FSA review (FSA, 2009).

Similar to the findings of the 2009 FSA review, this review of literature also found that views of functional food vary depending on the combination of carrier product and added functional ingredient (FSA, 2009) and also includes findings that women and older people appear to have more positive attitudes towards functional foods (Bimbo et al., 2017; FSA, 2009). Perceived necessity of the product still appears to be a key influencing factor in the purchase and consumption of functional foods.

SRQ7 What are the gaps in current research?

Bimbo et al. (2017) highlighted that there have been a very limited number of systematic reviews on functional food. They suggest that further research should be done looking at a broader range of functional food products and also to explore the effect of other product characteristics on consumers' food choices, such as brand when associated with nutrition and health claims (Bimbo et al., 2017).

Kuster-Boluda & Vidal-Capilla (2017) also suggest that a greater number of variables that may influence attitudes towards functional foods should be considered, for example, perceived risk and the influence of the container etc. They also propose that it would be beneficial to compare their study carried out in Spain with studies in other countries, particularly the US as this is the number one country regarding functional food consumption (Menrad, 2003 cited in Kuster-Boluda & Vidal-Capilla, 2017).

Sandmann et al. (2015) highlight the need for non-hypothetical studies that are based on revealed measures of consumer choices for functional foods.

Santeramo et al. (2018) identify a need for further research to explore consumers' attitudes towards functional food, with particular focus on countries where this is still weakly investigated.

Conclusions/summary

It is not possible to conclude from the reviewed literature whether consumers are accepting of functional foods in general. This appears to depend on the specific product, and in particular, the overall health perception of the functional food and the combination of 'carrier' food and added ingredient. Certain functional foods therefore appear to be more readily accepted by consumers than others.

A range of both product-related and consumer-related factors influence consumers' willingness to consume functional foods. Further research needs to be done to investigate the influence of health awareness and/or a healthy lifestyle has on consumption of functional foods as this review highlighted conflicting results. Age, gender, education level, and family structure have also been found to influence consumers' decisions to purchase or consume functional foods.

There is evidence to suggest the demand for functional foods is generally increasing, future research into consumer attitudes towards functional foods must consider a wider range of influencing variables and also compare studies across countries and cultures.

Cultured meat

Key findings

- Survey data in the UK indicates that 16% - 19% of consumers would eat cultured meat, 42% - 62% would not, and 19% - 40% are undecided.
- The most pressing concerns about cultured meat for consumers are around food safety and health impacts.
- There is not yet data tracking attitudes over time, though this is now starting to be collected, and there is reason to believe that acceptance will rise over time.

Overview of literature

Review based on 23 papers comprising 9 review and 14 empirical. Of the empirical papers 10 were quantitative and 4 were qualitative. Empirical papers explored consumer perceptions in the UK, Belgium, the USA, New Zealand, Canada, Australia, Switzerland, the Netherlands, Italy, Portugal, and other parts of Europe.

Key topics explore by papers included:

- Consumer perceptions of cultured meat.
- Perceived benefits and risks of cultured meat.
- Factors affecting acceptance of cultured meat.

Brief explanation of what the technology is

Cultured meat is meat 'grown from animal cells in a culture medium rather than being taken from slaughtered animals' (Bryant & Barnett, 2018, p.8). Stem cells are taken from an animal and grown in a cultivator which provides the warmth and nutrition they need to grow. Producing meat in this way has the potential to mitigate many of the animal welfare, public health, and environmental problems associated with rearing animals for meat (O'Keefe et al., 2015; Verbeke et al., 2015).

SRQ1 What are the public's views on the technology?

In a review of 14 empirical studies, Bryant and Barnett (2018) conclude that most consumers appear to be willing to try cultured meat, though relatively few would choose it over conventional meat. The authors point out that, in practice, this will depend on a number of factors such as price, product quality, and popularity, which cannot be accounted for since cultured meat products are not currently available. They also identify several perceived benefits, concerns, and areas of uncertainty.

On a personal level, consumers often characterise cultured meat as unnatural, a perception which sometimes underpins a disgust response according to focus groups (Verbeke, Marcu et al., 2015; n = 179). An experimental study in Switzerland (n = 204) has linked this perceived unnaturalness and evoked disgust to rejection of cultured meat (Siegrist, Sutterlin & Hartmann, 2018).

These perceptions may be linked to safety concerns about cultured meat (Bryant & Barnett, 2018; O'Keefe et al., 2016; Verbeke, Marcu et al., 2015). This is a concern which is often raised in focus groups, and is the most common concern for consumers in the UK according to a survey (n = 2,082) by The Grocer (2017) cited in Bryant and Barnett (2018). However, as Bryant and Barnett (2018) point out, consumers on average appear to rate cultured meat as safe overall when asked directly about its safety. This is based on survey data from the USA (n = 673; Wilks & Phillips, 2017) and Belgium (n = 180; Verbeke, Sans & Van Loo, 2015). Linked to this is a concern about the healthiness or nutritional quality of cultured meat (Verbeke, Marcu et al., 2015). Consumers often thought cultured meat would be less healthy than conventional meat.

In addition, consumers have concerns about the taste, texture, and appearance of cultured meat. O'Keefe et al. (2016) highlighted such concerns in focus groups (n = 40), and reported participants wanting to be able to compare the product side-by-side with conventional meat. Several studies in Bryant and Barnett's (2018) review found concerns around taste and other sensory aspects of cultured meat.

On a societal level, there are concerns around the loss of farming and the economic and cultural implications of this, energy consumption, and some suspicion of corporate drivers of the technology (Verbeke, Marcu et al., 2015; O'Keefe et al., 2016). In particular, consumers wanted to be assured that there would be adequate regulation and control of the technology to ensure product safety and quality, as well as clear transparent labelling and information provision (Bryant & Barnett, 2018; O'Keefe et al., 2016; Verbeke, Marcu et al., 2015).

Consumers also perceived many potential benefits of cultured meat. The most commonly perceived benefit was avoiding animal slaughter, which both vegetarians and meat-eaters discussed positively (Bryant & Barnett, 2018; O'Keefe et al., 2016). Consumers also recognise the potential for environmental benefits, especially in relation to greenhouse gas emissions (Bryant & Barnett, 2018; Verbeke, Sans & Van Loo, 2015).

Although consumers mainly perceived societal rather than personal benefits (Verbeke, Marcu et al., 2015), there is evidence that consumers are open to health and safety benefits. In particular, O'Keefe et al. (2016) found that UK consumers discussed the potential to provide a higher quality 'purer' product, possibly with added vitamins and minerals. They also discussed cultured meat as a way of avoiding food scares related to animal agriculture such as BSE. More recently, Baumann and Bryant (2019) have investigated the impact of nutritionally enhanced cultured meat, finding that although concerns about naturalness were unaffected, consumers anticipated that the suggested enhancements which included replacing saturated fat with omega 3 oils, would have an adverse affect on taste, and therefore purchase intent was unaffected.

Survey data in the UK indicates that about 16% - 19% of consumers would eat cultured meat, 42% - 62% would not, and 19% - 40% are undecided (The Grocer, 2017; Surveygoo, 2018; YouGov, 2013).

SRQ2 How do views differ depending on the type of technology?

In a review of several alternative proteins, Hartmann and Siegrist (2017) conclude that acceptance of each option varies based on product attributes and experience. This may include the degree of processing and sensory characteristics.

Several studies drew analogies between public views of cultured meat and genetically modified foods. Bryant and Barnett (2018) point out that many of the demographic trends in acceptance of these technologies are similar, and there is some evidence that consumers relate to them in similar ways (Verbeke, Marcu et al., 2015). Verbeke, Sans and Van Loo (2015) report Frewer et al.'s (2011) finding that technologies perceived as having a 'bioactive' component tend to raise more concerns since they are perceived as unpredictable.

However, O'Keefe et al. (2016) found that people generally perceived cultured meat more positively than genetically modified foods. They reported some participants comparing cultured meat to microwave meals, reflecting that they would have been strange in the past. The authors suggest this was due to negative press coverage of genetically modified foods relative to cultured meat, which was relatively unknown. Indeed, Bryant and Dillard (2019) found that different media framings of cultured meat affected consumer attitudes towards the technology. The authors also point out that media coverage of genetically modified foods was often driven by specific events such as food scares.

SRQ3 What shapes the public's views?

Verbeke, Sans and Van Loo (2015) argue that the public perception of cultured meat is likely to be shaped by perceived benefits and risks, trust in science, and media coverage as well as product attributes. Hartmann and Siegrist (2017) concur that product attributes are important and say that sensory properties are likely to be crucial, as consumers will not compromise on this.

Bryant and Barnett (2018) identify several factors which appear to affect acceptance of cultured meat. Information provision (both positive and negative) had an effect on consumer attitudes towards cultured meat in an experimental study in the Netherlands (n = 190; Bekker et al., 2017). Verbeke, Sans & Van Loo (2015) also found evidence that positive information about the benefits of cultured meat led to higher willingness to eat it. Likewise, more technical descriptions of cultured meat resulted in lower acceptance than less technical descriptions in an experimental study in Switzerland (n = 298; Siegrist et al., 2018).

Bryant and Dillard (2019), meanwhile, found that framing cultured meat as a high-tech innovation led to lower acceptance compared to framing it as having societal benefits, or being very similar to conventional meat. Bryant and Barnett (2018) comment that research thus far has always framed cultured meat as a future technology, which has an effect on the findings, also. Similarly, Bryant and Barnett (2019) find that nomenclature has an impact on public perceptions, with names like 'clean meat' being more appealing than names like 'lab grown meat'.

There is also evidence that consumers who are more familiar with cultured meat are more likely to say they would eat it (Bryant et al., 2019). Indeed, focus group participants in Verbeke, Marcu et al. (2015) were initially hostile to the concept, but were more accepting of the technology by the end of the discussion.

Other factors influencing acceptance of cultured meat are the price, and the perceived market share (Slade, 2018). Consumers were more likely to choose cultured meat over alternatives if the price was lower, and if they were told that it had a higher market share. The author speculates that this could be due to wanting to conform to social norms, or consumers may be using market share as an indicator of product quality.

SRQ4 Do different types of people hold different views?

Bryant and Barnett (2018) highlight various findings related to demographic trends in acceptance of cultured meat. In general, men are more accepting of cultured meat than women (Surveygoo, 2018; The Grocer, 2017; Wilks & Phillips, 2017; YouGov, 2013), and politically liberal people are more accepting than conservatives (Bryant, Szejda et al., 2019; Wilks & Phillips, 2017; Wilks et al., 2019). Others find that younger consumers (Eurobarometer, 2005; YouGov, 2013; Surveygoo, 2018; The Grocer, 2017) and those with more education are more likely to eat cultured meat (Flycatcher, 2013; Pew Research, 2014; Slade, 2018). Meanwhile, in focus groups in New Zealand (n = 69) Tucker (2014, cited in Bryant and Barnett, 2018) found that more urban-dwelling consumers were more positive towards cultured meat than more rural-dwelling consumers, a result replicated by Shaw and Mac Con Iomaire (2019). Interestingly, Wilks and Phillips (2017) found that vegetarians are more likely to have positive views of cultured meat compared to omnivores, but are less likely to want to eat it themselves. The latter result has been replicated by Bryant et al. (2019) and Flycatcher (2013), indicating that the main market for cultured meat is meat-eaters, not vegetarians.

There is also some evidence that people from different cultures and countries have different views of cultured meat. This can be seen in qualitative studies (Bekker et al., 2017; n = 30) and in some survey data. Eurobarometer (2005; n = 32,897) finds some differences between European countries in acceptance of cultured meat, whilst Surveygoo (2018; n = 1,000) found substantially higher acceptance in the USA compared to the UK.

Our expert interview on this topic confirmed many of these associations: higher acceptance is observed amongst left-leaning individuals, urban-dwellers, younger people, and men.

SRQ5 How do views affect behaviour such as food choices?

Our expert interview indicated that this is an issue for cultured meat research. Since there are no products available yet, all of the research is hypothetical in nature, and self-reported intentions towards a product do not necessarily reflect actual purchasing behaviour.

Nonetheless, two studies used choice experiments to observe hypothetical choices between cultured meat, plant-based meat, and conventional animal meat. Slade (2018) found in a Canadian sample (n = 533) that, given equal prices, 65% of consumers would choose a conventional beef burger, 21% would choose a plant-based burger, 11% would choose a cultured meat burger, and 4% would make no purchase. Similarly, Lusk (2019) found in an American sample (n > 1,800) that, given equal prices, 72% chose conventional beef, 16% chose plant-based pea protein meat, 7% chose animal-like plant-based meat, and 5% chose cultured meat.

SRQ6 How have views changed over time?

As highlighted by Bryant and Barnett (2018), there are currently no longitudinal studies which track views of cultured meat over time, though this is now being carried out in the USA as part of Sentience Institute's (2017) Animal Farming Attitudes survey. Bryant and Barnett (2018) comment that acceptance in the future will be driven by increased familiarity, increased perceived feasibility, regulation, commercial availability, media coverage and the ability to try cultured meat.

There is some evidence to suggest that views will become more positive over time – Verbeke, Marcu et al. (2015) observed focus group participants becoming more positive as they discussed the topic, while O'Keefe et al. (2016) observed participants drawing analogies to microwave meals as another food technology which once seemed improbable.

Our expert interview highlighted a shift in attitudes towards animal products in terms of animal welfare and sustainability, which may lead to more positive attitudes to animal product alternatives.

SRQ7 What are the gaps in current research?

A major gap in the research currently is longitudinal studies which observe acceptance of cultured meat over time (Bryant & Barnett, 2018; Hartmann & Siegrist, 2017). This work is starting to be done as part of Sentience Institute's (2017) Attitudes Towards Animal Farming survey, which was first done in 2017 and will be done annually going forward according to communication with the research director, Jacy Reese.

Bryant and Barnett (2018) identify some gaps in the research on cultured meat acceptance, including longitudinal studies observing acceptance over time. Bryant and Dillard (2019) and Hartmann and Siegrist (2017) also highlight the need for studies observing the change in attitudes towards cultured meat over time.

Additionally, research comparing the effect of providing different types of information on cultured meat acceptance would be useful (Bryant & Barnett, 2018; Verbeke, Sans, & Van Loo, 2015). For example, messages highlighting the environmental benefits, animal welfare benefits, or health and safety benefits. Bryant and Dillard (2019), meanwhile, call for content analyses of the frames used by media and cultured meat producers. The authors find evidence that these frames affect consumer acceptance of cultured meat, and several studies highlight the importance of media coverage in shaping consumer perceptions (O'Keefe et al., 2016; Verbeke, Sans & Van Loo, 2015).

Finally, our expert interview on this topic highlighted the need for research looking at drivers of attitudes, but also a conceptual exploration of what meat is – is it only the flesh of a slaughtered animal? This may be relevant to policy around cultured meat in particular.

Conclusions/summary

Overall, consumers have mixed views towards cultured meat. They perceive mainly societal benefits around the environment and animal welfare, though some discuss the possibility of improving meat quality as well as health and safety. Personal barriers include perceived unnaturalness, safety concerns, and concerns around price and sensory characteristics. Some consumers also have societal concerns about regulations and the impact on traditional farming.

Views are similar to views of genetically modified foods in some respects, though are generally more positive. Views are affected by framing, different explanations, and information provision. We see higher acceptance amongst men, younger people, more left-leaning people, more urban consumers, more educated consumers, and omnivores. Many of these trends are similar to those in genetically modified food.

It is likely that more familiar consumers are more accepting of cultured meat, though we do not yet know how acceptance might change over time. Research so far has been limited by its hypothetical nature.

Novel food processes

Key findings

- Familiarity with and acceptance of eating insects or food derived from insects is growing rapidly.
- Product design and relevant comparators have shifted from whole insect, meat substitute to environmentally beneficial 'sweet treat' with no visible insect portion.
- Saleable and appropriate products are increasingly available and the market value is growing substantially.
- Health conscious, environmentally aware people are the forefront of uptake.

- Media attention to the topic is acting to increase awareness and promote sector growth.

Overview of literature on the acceptance of insect protein as human food

As an example of a novel food, we have chosen to concentrate on insects as food. Although over 2 billion people worldwide consider eating insects traditional, this is a novel food process in the UK and other 'Western' countries (Collins et al., 2019).

This review is based on 17 key references identified through expert recommendation, all published within the past six years. Included are a crucial FAO report on this topic (van Huis et al., 2013), a European FSA scientific opinion on risk profile (Finke et al., 2015), two systematic literature reviews (Hartmann and Siegrist, 2017a, 2017b). Among the empirical papers, one summarised a qualitative product design investigation (Clarkson et al., 2018), another summarises a European workshop on the topic of insects as food and feed held in 2015 (Payne et al., 2016), four examined determinants of consumer acceptance and actual consumption of insect products (Tan et al., 2015; Caparros Megido et al., 2016; Hartmann and Siegrist, 2016; House, 2016) and one surveyed >1000 adults and children in the UK and Europe using mixed survey and choice-preference techniques (Collins et al., 2019).

These papers explore and review consumer perceptions of insect protein for human consumption in a largely 'Western / developed' context. There exists a further and substantial body of literature covering the consumption of insects in both African and Asian contexts where insect eating is embedded in local cultures. We do not consider those here.

Brief explanation of what the technology is

The consumption of insects as a food source, occurs at a global scale with over 2 billion people seeing it as traditional (van Huis et al., 2013). This practice is not currently extensive in mainstream western culture where it is often met by a range of barriers, leaving consumption of insects as food often being seen as a taboo (McDade and Collins, 2019).

Insect protein has great potential to be used as reliable alternative or supplement to vertebrate 'meat' consumption and offers relative advantages over traditional animal protein sources when entry barriers are overcome. One advantage is the lower environmental impact of mass-rearing insects in terms of (for example) water, greenhouse gases and ammonia. Furthermore, insects are highly nutritious and have been found to be healthier than some other meat alternatives (van Huis et al., 2013; Dickie et al., 2019).

Production of farmed insect protein is increasing in volume across Europe and North America with substantial investment in technologically advanced farming systems. Predictions in America indicate an approximately 20-fold growth in market between 2017 and 2024 with a $ volume in the region of $100M (Ahuja and Deb, 2018). Insects are also being integrated to the animal feed market. The larvae (maggots) of several fly species are increasingly used in dog, cat, chicken and fish feedstocks (Sánchez-Muros, Barroso and Manzano-Agugliaro, 2014). One significant advantage in this non-human consumption is the potential efficiency of insects in re-processing of food and agricultural waste to commercial purpose.

In recent years edible insects have attracted increasing interest in Western populations due to their nutritional and environmental advantages (Tan et al., 2015). The high health value of insects as food is due to the low content of saturated fatty acids, the high digestibility and the presence of Omega 3. Insect-based foods can also deliver environmental benefits because of a reduction in carbon emissions, the lower requirements of water and space, and their high biomass conversion rate. This high nutritional value with high environmental sustainability is promoting insect eating for human nutrition all over the world (van Huis et al., 2013; Santeramo et al., 2018).

SRQ1 What are the public's views on eating insects?

In the UK and other 'Western' countries where insect foods are largely unfamiliar, first contact with the concept of insect eating mostly triggers a disgust response. Various European consumer surveys have indicated low willingness to consume insects (Hartmann and Siegrist, 2017a), and, when given a choice, respondents have been seen to prefer non-insect products over insect-containing products (Hartmann and Siegrist, 2016).

Familiarity is growing, however. In the last few years, public and scientific interest in novel food from insects has risen (Tan et al., 2015). In an empirical study (n= 71) that focused on younger people (18-25 years), the level of willingness to try insects was high, with 69% of the sample curious about tasting insects. Participants were both intrigued and disgusted about the idea eating insects (Clarkson et al., 2018).

The largest available online UK/European survey (n=1020)(Collins et al., 2019) found that 97% of participants were aware that insects can be cooked for food. More than one-third had eaten insects before and had, on average, enjoyed the experience.

Other studies analysing consumer behaviour towards the consumption of insect-based food and exploring the main barriers and drivers for these novel food products reinforce that cultural background and individual experiences play an important role in acceptance. Consumers are more willing to eat processed insect-based foods compared to unprocessed foods especially when they are incorporated into familiar food items (studies cited in Caparros Megido et al., 2016) .

SRQ2 How do views differ depending on the type of technology?

Attitudes towards different applications of the same technology

For insect-based food products the single biggest factor found to affect acceptance is insect visibility. In British children (n=161) provided with a choice of insect food images to rank for preference, all those with a visible insect or insect part ranked lower than those made from ground insect products (Collins et al., 2019). The authors found the same pattern is true in adults (n=1020), especially in those with no previous experience of eating insects.

The nature and presentation of the insect product is paramount as is the comparator. Product design surveys indicate that consumers are more accepting of a sweet snack or breakfast option, rather than a meat substitute. Insects used as a protein packed ingredient for convenient snack, drink, or breakfast products are substantially more acceptable than those framed as a savoury meat alternative (Clarkson et al., 2018).

A review of several alternative proteins concludes that acceptance of each option varies based on product attributes, meal context and previous experience (Hartmann and Siegrist, 2017a). The information medium is also influential and branding, advertising message and the route it is received through all play an important role in growing acceptance (Santeramo et al., 2018).

SRQ3 What shapes the public's views?

The public's views seem to be largely shaped by the social context and degree of familiarity with insects as food and by the way in which the insects or their protein are presented. The largest survey (n=1020; respondents principally from U.K. & France) indicated the top four publicly-perceived benefits are 'Feeding the world', 'Low environmental impact', High protein content' and 'High nutritional qualities'(Collins et al., 2019).

An initial disgust reaction to insect eating comes from a cognitive process when assessing foods and can arise with perceived or real associations of insects to objects of core disgust, which include pathogens and pathogen-related stimuli.

Humans have strong and adaptive food neophobia, and as in the West insect protein products are seen as novel, this influences consumer perception and expected experience on trying it (McDade and Collins, 2019). The degree of novelty correlates strongly with unwillingness to try unfamiliar foods and is common when the social context is lacking. Rapidly increasing familiarity is providing an opportunity for observability and the developing market share indicates a shift in levels of neophobia (Santeramo et al., 2018; McDade and Collins, 2019).

For insect-based food products the single biggest factor found to affect acceptance is insect visibility. In British children (n=161) provided with a choice of insect food images to rank for preference, all those with a visible insect or insect part ranked lower than those made from ground insect products (Collins et al., 2019). The authors found the same pattern is true in adults, especially in those with no previous experience of eating insects.

Availability and familiarity grows and a recent study in the Netherlands used available ‘convenience snacks’ to identify factors that would affect ongoing consumption such as price, taste, availability, and ‘fit’ with established eating practices, from those that influence an initial experience (House, 2016).

SRQ4 Do different types of people hold different views?

Within populations unfamiliar with insect eating, there are different levels of willingness to both try and regularly consume insects among demographic groupings. Age has been found to show differences. Children are slightly more open to ‘first tries’ than adults; previous experience (often associated with travel or cultural background), regular exercise patterns and ‘green shopping’ all indicate greater receptivity (Collins et al., 2019). Though several studies identify slightly more receptivity in men than women, there is little substantial effect of gender (Hartmann and Siegrist, 2017b; Collins et al., 2019).

One expert suggested that part of the discussion surrounding insect protein has moved to production methods and there is now a demographic segment that will remain opposed to insect, and any other animal, product.

SRQ5 How do views affect behaviour such as food choices?

The demographic groups currently identified as more likely to purchase insect-protein products are those already somewhat invested in ‘green’ and ‘healthy’ lifestyle choices. Being a meat-eater rather than vegetarian also promotes purchase and consumption. Some findings do contrast, with willingness to pay being found to rise with age in some studies, but not in others (Collins et al., 2019).

The growth in environmental awareness and in appropriate product availability (such as nutrition snacks), create availability and opportunity for a pro-insect food choice. Shared culture and experience of group movements will also contribute to this (Tan et al., 2015).

SRQ6 How have views changed over time?

According to Tan et al. (2015), interest for insects as food has been growing within Western countries in recent years. However none of the reviewed literature explored in detail how the publics' views towards insects as food have changed over time. Additionally, edible insects, as an example of a novel food process, were not included in the 2009 review (FSA, 2009).

There are examples of other protein sources that were seen in the past as unconventional but have since become popular. Examples include sushi in the West (Bestor, 2000 cited in Collins et al., 2019) and lobster in America (Luzer, 2013 cited in Collins et al., 2019). Therefore it can be suggested that the same might happen for insects as there is also increasing evidence that Westerners are rapidly expanding the range of foods they conceive as edible (Tucker, 2013 cited in Collins et al., 2019).

One expert suggests that the clear growth in interest, range of available products and commercial production in Western countries may indicate that the perception of insects as human food is shifting towards acceptance.

One expert suggested that in many less developed countries the emergence of affluent middle classes tends to lead to a decline in consuming insects as food. Interestingly, insect consumption in these countries remains strong at both high income levels where it can be perceived as a traditional delicacy and at low income levels where it is integral to subsistence nutrition.

SRQ7 What are the gaps in current research?

The insect species being farmed currently in developed countries are a mix of traditionally-consumed (for example, mealworms, crickets and locusts) and human-novel (for example, black soldier fly, BSF) (Ahuja and Deb, 2018). For the more novel we need to have a better understanding of nutritional profile, effects of their feedstock (agricultural waste for example) on this and effects of long-term consumption.

There is also a need for research on the conditions of farming, technological treatment and processing methods and on toxicological, microbial and hygienic safety (Boppré and Vane-Wright, 2019). The possible allergenic potential of insects should also not be ignored (Hartmann and Siegrist, 2017b).

In addition to this biological and engineering research there is a need for research and development of appropriate regulation and ethical standards of welfare to guide the emergent industry (Finke et al., 2015).

Conclusions/summary

The reviewed literature suggests that the initial consideration of insects as food generally triggers a disgust response in Western consumers. This disgust reaction is shown to be linked to food-neophobia and a lack of familiarity with eating insects. However, familiarity and interest in insects as food is growing in Western countries and the production of farmed insects in Europe and North America is increasing.

Insect visibility in food is found to be one of the biggest factors influencing acceptability of edible insect products.

From the reviewed literature, there is no conclusive evidence on demographic differences; however age is suggested to influence willingness to try insects. Additionally consumers who are already somewhat invested in ‘green’ and ‘healthy’ lifestyle choices are suggested to be the most likely consumers.

None of the reviewed literature examines in detail how attitudes towards eating insects in Western countries has changed, however interest appears to be increasing.

In addition to biological and engineering research on the practicalities of eating insects on a wider scale, there is also a need for development of appropriate regulation that will affect consumers.

Food from a cloned animal

Key messages

- Most consumers (including expert stakeholders) are critical towards this technology and would not purchase meat or milk that comes from cloned animals mainly due to food safety, ethical, animal welfare, absence of labelling, economic and environmental concerns.

- In the last decade, consumer attitudes towards food from a cloned animal have not changed and remain unsupportive due to similar reasons including food safety, animal welfare and ethical concerns. However it appears that the current consumer views on this technology are more formed than those of 2009.
- Higher acceptance of food from a cloned animal is seen amongst men, more left-leaning individuals, more urban consumers and primary grocery shoppers and families with older children.
- Actual behaviour in terms of purchasing food from a cloned animal might not reflect the indicated low acceptance of this food, due to the hypothetical nature of the available studies. This is also highlighted by findings that consumers indicate price, good taste and quality and convenience rather than ethical concerns as factors that mainly drive their purchasing behaviour.

Overview of literature

Review based on 9 papers comprising 3 review, 5 empirical and 1 position paper (grey literature). Of the empirical papers 4 were quantitative, 1 was qualitative. The empirical papers explored consumer perceptions in Ireland, US, Japan and Chile. The review also included 1 grey literature source indicating consumer attitudes in Europe.

Key topics explored by papers included:

- Consumer perceptions of food from a cloned animal.
- Factors affecting acceptance of food from a cloned animal.
- Factors affecting purchasing behaviour of food from a cloned animal.

Brief explanation of what the technology is

The European Group on Ethics in Science and New Technologies to the European Commission has defined cloning as ‘the process of multiplying single organisms by means of asexual reproduction to create a population of identical individuals’ (Schnettler et al. 2015). Embryo cloning and somatic cell nuclear transfer are the two main techniques for animal cloning with the latter being the most often used for this purpose (Aizaki et al. 2011; Brooks and Lusk, 2011). In the process of somatic cell nuclear transfer, the nucleus of an unfertilised egg cell is replaced with the nucleus of a body cell from the animal to be cloned. When an embryo forms it is then transferred to a surrogate mother where it develops until birth. As a relatively new technology cloning aims to replicate ‘elite’ breeding animals such as fastest growing pigs or highest yielding dairy cows. This offers high productivity and consistent quality of livestock (Murphy et al. 2011). Generally, these animals are not produced for meat or dairy consumption purposes, partially due to the high costs (a cloned offspring costs $8000 - $15,000) (BEUC, 2015; Saeed et al. 2015).

SRQ1 What are the public’s views on the technology?

Both quantitative and qualitative studies on consumer attitudes are consistent in their conclusions that most consumers would not purchase meat or milk that comes from a cloned animal (Rollin et al. 2011; Brooks and Lusk, 2011; Schnettler et al. 2015; Aizaki et al. 2011; BEUC, 2015).

Consumers also appear to be critical of the cloning technology itself. In particular, a qualitative study by Rollin et al. (2011) indicates that acceptance towards the animal cloning technology among EU consumers has been low (based on the outcomes of a Eurobarometer survey (2008) on Europeans’ attitudes towards animal cloning (n=25000)). Furthermore, the European Consumer Organisation in their position paper also refers to this survey to emphasise that majority of EU consumers considered cloning for food production unjustifiable (BEUC, 2015). In contrast, Britwum et al. (2018) based on field experiments in four locations in the US (n=148) highlighted consumer willingness to enable food products (i.e. milk) from a cloned animal in the food supply. However, majority of respondents in this study had a neutral or negative opinion on cloning technology itself. Whilst most consumers disapprove the practice of cloning for food production, certain purposes such as preserving endangered species or solving worldwide food problems are considered somewhat acceptable (BEUC, 2015; Rollin et al. 2011).

A variety of reasons are identified that form this sceptical perception. For example, Rollin et al. (2011) highlights that consumers have considered animal cloning as morally wrong. In addition, EU consumers have also expressed concerns over the long-term effects of animal cloning on environment (BEUC, 2015). Various studies have noted the persistent concern about the presence of labelling. In particular, consumers expressed the need for food from a cloned animal to be labelled in order to make informed food purchase decisions (Britwum et al. 2018; Rollin et al. 2011). Finally, consumers have also raised the issue of the safety of food from a cloned animal according to a web-based survey (n=2256) by Brooks and Lusk (2011) and from findings in literature and expert interviews by Murphy et al. (2011). In addition Murphy et al. (2011) refers to literature highlighting cost effectiveness and potential trade implications, also being among the main consumer concerns from using this technology (Rosenbergen, 2007; Suk et al., 2007).

Interestingly, Murphy et al. (2011) interviewing expert stakeholders (n=19) in Ireland (from public/private sectors, NGOs and universities) point out that the respondents predict a negative response among the public to the use of cloned animals for food purposes. Respondents believed that this could be due to associations with human cloning and animal welfare also supported by findings of Saeed et al. (2015). This study also sought the personal viewpoints of expert stakeholders towards cloning for food production which was largely viewed with scepticism in the short term. A more positive view on the technology was observed among stakeholders possessing a technology background.

SRQ2 How do views differ depending on the type of technology?

A couple of studies drew comparisons between public views of food from a cloned animal and genetically modified (GM) foods. Rollin et al. (2011) found that there are similarities in terms of consumers' awareness and acceptance of these two technologies. For both technologies the consumers shared a good awareness while having low acceptance. However, the study by Schnettler et al. (2015) comparing the acceptance of milk obtained from cloned, GM and conventionally bred cows among working adults and university students report some differences in support. In particular, the results of the study indicate that there was a greater rejection of cloning among university students whereas working adults were more critical towards genetically modified foods.

Based on a web-based survey (n=611) from Greater Tokyo, Aizaki et al. (2011) found that consumer attitudes towards food from a cloned animal didn't change between two types of cloning techniques (i.e. embryo cloned beef and somatic cell cloned beef). In both cases consumers were equally sceptical regarding the consumption of the two types of cloned meat.

SRQ3 What shapes the public's views?

Rollin et al. (2011) note that generally European consumers tend to have low confidence in novel food technologies due to Member States mismanaging food safety issues in the past.

Perception and individual characteristics appear to be essential factors in shaping consumer views of food from a cloned animal. As noted by Rollin et al. (2011), some research suggests that consumer acceptance is driven by risk perception (Frewer, Howard, & Aaron, 1998). For example, whether the risk is perceived to be involuntary, unnatural, unknown to scientific experts, 'hidden' by regulatory institutions or may affect health rather than the environment can have an influence on consumer attitudes (Gaskell, 2000; Siegrist, Stampfli, Kastenholz, & Keller, 2008; Slovic, 1987; van Kleef et al., 2006). Rollin et al. (2011) also indicates to arguments that suggest that consumer acceptance also depends on the perception of the potential benefits from novel food technologies (Ronteltap et al., 2007). As highlighted by Murphy et al. (2011) some of the perceived benefits include disease resistance, productivity, and product consistency. Meanwhile, Brooks and Lusk (2011) found that the perception of reality correlates with people's willingness to eat cloned meat. The study found that consumers are more willing to eat food from a cloned animal if they believe that cloned food products are already being sold in grocery stores. There is also some evidence that indicate to consumers' individual characteristics (for example, habits, extent of trusting others, preconceptions; importance to be perceived as progressive among peers etc.) and moral and ethical values that may influence their acceptance of cloned meat (Aizaki et al. 2011; Rollin et al.; Brooks and Lusk, 2011; Murphy et al. 2011; Saeed et al. 2015).

Aizaki et al. (2011) observed that previous/basic knowledge on food cloning may influence consumer attitudes towards food from a cloned animal, however this occurred in a limited sample size (n=86 & n=76). The authors also point out that new and technical information did not influence consumers' attitudes. In contrast, Britwum et al. (2018) observed that the consumer acceptance of cloned food products was driven by increased perceived knowledgeability on this issue. These mixed outcomes were supported by Rollin et al. (2011) with 'some studies finding that new information has no significant effect, and others finding positive or negative effects of new information'. Related to the issue of information and new knowledge Cheftel et al. (2011) found that trust in certain sources (for example, authorities, experts, media etc.) is a crucial determinant of acceptance of novel technologies including for food from a cloned animal.

Furthermore, Rollin et al. (2011) observed that labelling can influence acceptance of cloned food products as 'people are inclined to accept the risk of consuming new food products, if it is under their own control'. Whereas, Brooks and Lusk (2011) found that Internet access may also be a factor in consumer purchasing behaviour of cloned food products.

Meanwhile, Murphy et al. (2011) interviewing Irish stakeholders found that aspects such as predicted economic benefits, consumer and public perception, ethical implications, animal welfare, and social justice influence their acceptance or rejection of animal cloning for food purposes.

SRQ4 Do different types of people hold different views?

Various sociodemographic factors appear to determine acceptance of food from a cloned animal. Some studies suggest that women are less accepting of food from a cloned animal, whilst men are more likely to believe that cloned meat is safe for consumption (Aizaki et al. 2011; Britwum and Bernard 2018, Brooks and Lusk, 2011). It was also observed that younger people (Britwum et al. 2018) and University graduates (Brooks and Lusk, 2011) are more supportive of food from a cloned animal than older generations and those with only a high school diploma. However, the results from Schnettler et al. (2015) contradict this finding as the study did not find any significant differences in consumer acceptance across different age groups and education levels.

Brooks and Lusk (2011) found that people with young children are less accepting than those with children over the age of 12 in their household. There is also some evidence that consumers from urban areas are more accepting of cloned food products than more rural-dwelling consumers (Schnettler et al. 2015; Britwum and Bernard, 2018).

Furthermore, Britwum and Bernard (2018) observed higher consumer acceptance for cloned food products amongst environmentally aware left-leaning individuals and primary grocery shoppers.

SRQ5 How do views affect behaviour such as food choices?

The available research on acceptance of cloned food products is hypothetical in nature and may not reflect actual purchasing behaviour if such food would be available on the market. Particularly, Rollin et al. (2011) point out to studies that suggest price, good taste and convenience as the main factors affecting consumer behaviour in today's marketplace including for products from novel technologies (Bruhn, 2008; Fell et al., 2009; Spence & Townsend, 2006; Bruhn, 2008; Food Marketing Institute, 2005). This can also be seen in the study by Britwum et al. (2018) where consumers who considered food price in their purchasing behaviour were more accepting of food from coned animals than those for whom price was not an issue. In addition, cost and quality was also cited as the primary influence for Irish stakeholders in food purchase decisions rather than ethical concerns (Murphy et al. 2011).

From a web-based survey (n=2256) Brooks and Lusk (2011) found that approximately 40% of consumers would likely alter their purchasing behaviour if they learned that the food came from a cloned animal. Britwum et al. (2018) found that consumer willingness to purchase food from a cloned animal were influenced by personal views on environment and animal ethics.

Aizaki et al. (2011) conclude that consumers ‘would not welcome the use of animal cloning in food production’ considering they have a greater support for conventional products. Likewise, BEUC (2015) highlight that majority of EU consumers have expressed unlikeliness to buy food from a cloned animal regardless of its safety standards.

SRQ6 How have views changed over time?

There are limited number of studies which track the consumer acceptance of food from a cloned animal. Brooks and Lusk (2011) highlights some previous opinion polls in the US that have shown increased consumer acceptance of cloned food products in a short period of time (2005-2008).

As seen in the outcomes from an evidence review of Public Attitudes to Emerging Food Technologies by Brook Lyndhurst (2009), consumer attitudes towards food from a cloned animal has not changed and remains unsupportive. Similar reasons for this scepticism among consumers remain including food safety, animal welfare and ethical concerns. From this review it appears that in the EU consumer views on this technology are now more formed, with a 2010 survey finding that 'Europeans have strong reservations about animal cloning in food production and do not see the benefits, and feel that it should not be encouraged' (Eurobarometer Special Report on Biotechnology, 2010, cited in BEUC, 2015, p.7). This contrasts with the findings of the 2009 review (FSA, 2009) which highlighted that a large proportion of the public did not have a firm view.

Schnettler et al. (2015) based on their study outcomes anticipate that the lower acceptance among young people will prevent the views becoming more positive over time once they become primary grocery shoppers for their homes. However, this assumption is in contrast with the observations by Britwum et al. (2018) finding young people more supportive of food from a cloned animal than older generations.

SRQ7 What are the gaps in current research?

Aizaki et al. (2011) highlight that there is limited information available on consumer acceptance of food from cattle clones. In addition, Britwum et al. (2018) suggest conducting more non-hypothetical studies expanding the range of products from cloned animals examined. The authors also highlighted the importance for future studies to investigate potential changes in consumer acceptance of food from the offspring of a cloned animal.

Conclusions/summary

Generally, consumers would not purchase meat or milk that comes from a cloned animal. However, some consumers believe that cloned food products should be allowed on the marketplace if labelled appropriately. They also appear to be critical of the cloning technology itself by mostly forming neutral or sceptical views. The main reasons that form this sceptical perception include ethics, animal welfare, food safety, absence of labelling, economic and environmental concerns.

There are similarities in views of food from a cloned animal with those of genetically modified foods, though there are differences in acceptance amongst different types of consumers (for example, university students, working adults). The factors that appear to influence the formation of consumer views include individuals' perception (of risks and benefits), personal characteristics, knowledge, new information, access to internet and the presence of labelling. Higher acceptance is seen amongst men, more left-leaning individuals, more urban consumers and primary grocery shoppers and more families with older children.

There is limited evidence on the historic trends on consumer acceptance of food from a cloned animal. There are also uncertainties how acceptance of food from a cloned animal might change over time. Future research needs on this technology include non-hypothetical studies, examination of broader range of products including of food from the offspring of a cloned animal.

3D printed food

Key findings

- Consumers in general tend to have low levels of knowledge and familiarity, and negative attitudes towards 3D printed food technology, though this is not universal
- Views towards 3D printed food can be influenced in various ways by food appearance, perceived safety, extent of processing, healthiness/nutrition and tastiness, knowledge and information, perceived 'fun to use', food technology neophobia and food neophobia.
- Informing or educating consumers about 3D printed food technology has been found to have a positive impact on the attitudes of some study participants.

- **Relevant aspects of 3D printed food technology to promote to consumers include 'fun to use', convenience, health and personalised nutrition, while also giving consideration to food content, the sensory qualities, level of processing.**

Overview of literature

The literature search identified very little literature on consumer attitudes towards 3D printed food technology. This review is based on 5 empirical papers comprising: 3 qualitative studies – notably all of which are based on the same small sample of Australian consumers: Lupton & Turner, 2018a, b, c; 1 quantitative study (Brunner et al. 2018); and 1 mixed method study which included technological aspects, sensory evaluation and a consumer survey though we report only the consumer survey results here[22] (Mantihal et al., 2019). These studies examine consumer attitudes in Switzerland (Brunner et al. 2018) and Australia (Lupton & Turner, 2018a, b, c; Mantihal et al., 2019). Additionally the review draws on 1 conference paper which provides background on the development of 3D printed food technology for sustainable food production (Soares & Forkes, 2014).

Key topics explored by the papers include consumer attitudes, knowledge and awareness towards 3D printed food technology and willingness to consume 3D printed food (Brunner et al. 2018; Lupton & Turner, 2018a,b,c; Mantihal et al., 2019); the formation of consumer attitudes towards this technology and resulting food concepts (Brunner et al. 2018); attitudes towards different types of 3D printed food (Lupton & Turner 2018a), including 3D printed cultured meat and insect-based products (Lupton & Turner 2018b) and to the 'promissory narratives' of reducing food waste and enhancing environmental sustainability (Lupton & Turner, 2018c).

In the work of Lupton & Turner (2018a,b,c) consumers were presented with written information and images of 3D printed products, while Mantihal et al. (2109) presented (and demonstrated) the real-life technology and example products to consumers; Brunner et al. (2018) relied on written descriptions of technology only (no images).

Brief explanation of what the technology is

3D printed technology (also known as 'additive manufacturing') is defined as 'a technology with which computer-aided design (CAD) software instructs a digital fabricating machine to shape 3D objects by the successive addition of material layers (ISO, n.a., Lupton & Turner, 2016)' (in Bruner et al. 2018, p389).

[22] The technological aspects were beyond the scope of the study, while the sensory evaluation was based on a sample of semi-trained respondents hence was excluded from the current analysis.

The technology is thought to offer a range of potential opportunities to improve health and nutrition (for example, preparing food for people with swallowing or other eating difficulties, to encourage children to eat healthy foods, to produce food designed to meet individual nutritional needs etc); improve food sustainability and reduce food waste (for example, by re-using discarded food, by enabling more efficient use of available foods); use of alternative food sources (for example, insects-based foods); production of cultured meat; and meet food needs in difficult situations such as disaster areas (Lupton & Turner 2018b,c; Soares & Forkes, 2014).

The 3D food printing process involves cartridges filled with soft edible matter, for example, food pastes, batters, and gels, which ‘are extruded through nozzles to generate products layer by layer, and can achieve intricate designs’ (Lupton & Bruner, 2018a, p1). Food that is fabricated using 3D printed technology can be personalised in many ways, for example, appearance, flavour, texture and nutritional value.

Examples of food products which have been created using 3D printing technology include chocolate, confectionary, sugar decorations, biscuits, pancakes, pizzas, pasta and entire meals (Lupton & Turner, 2018a). Some 3D printed food products (for example, novelty sweets, biscuits) are reported to have been available to the public for several years (Lipton et al. 2015; Sun et al. 2015 in Lupton & Turner, 2018c). Lupton & Turner (2018a) report that 3D printed food technology is starting to be used by chefs in fine-dining and in some German nursing homes for residents with chewing and swallowing difficulties. Technology for 3D printing chocolate at home is available in the UK (see http://chocedge.com/home.html).

SRQ1 What are the public’s views on the technology?

The limited evidence available suggests that the general public have low levels of knowledge and familiarity and generally negative attitudes towards 3D printed food technology (Brunner et al. 2018; Lupton, 2018a,b,c), though a study of university students, staff, and visitors found they were reasonably familiar and generally positive (see Mantihal et al. 2019). There is some evidence that participants are willing to try 3D printed foods and serve it to others (Lupton & Turner, 2018a; Mantihal et al. 2019), though this can vary depending on the product (Lupton & Turner, 2018a; see SRQ2 How do views differ depending on the type of technology?).

Brunner et al. (2018) in a quantitative study of Swiss consumers (n=260) found that while initial attitudes toward 3D-printed food were not unanimous, overall, they tended to be negative and ‘give little credit to 3D-printed foods’. The authors also found that attitudes towards this technology can become more positive through communication.

Lupton & Turner (2018a), in a qualitative study of Australian consumers (sample n=30), reported that most participants were ‘mystified’ about what 3D printed food was and would be used for, frequently asking, ‘Why bother using 3D printing to make food?’ (Lupton & Turner, 2018b). While several participants were willing to consider consuming 3D printed food, concerns remained about the safety of the production process regarding possible contamination by printer plastic, chemicals or bacteria, levels of additives and preservatives, the nutritious quality of such products, poor taste, artificialness, and possible nutrient loss by processing (Lupton & Turner, 2018c). Participants commonly described 3D printed food products as ‘‘unnatural,’ ‘too processed,’ ‘artificial,’ ‘unhealthy,’ and ‘not real’’ (Lupton & Turner, 2018b, p.11). Assumptions were also expressed that 3D printed food would somehow be ‘plastic’ and therefore inedible Lupton & Turner (2018c).

The extent of processing involved in 3D printing was a concern for many participants and for many also viewed as ‘unnatural’ (Lupton & Turner, 2018c). The technology was seen as being ‘a very artificial and highly processed way of preparing food’, with several of the examples of printed foods shown to participants found to be unacceptably ‘'unnatural'-looking’ (for example, slimy, too perfect, brightly coloured etc) (Lupton & Turner, 2018c). 3D printed food which looked reasonably similar to familiar foods was also ‘viewed with suspicion’ as being both too like but different to the familiar (Lupton & Turner, 2018c).

Some participants expressed views that 3D printed foods may be more suitable for social groups such as the elderly (who experience difficulties swallowing and lack food variety), the poor, the starving or homeless, local or globally (for example, those living in regions with food security problems), rather than for themselves or their families Lupton & Turner (2018b,c). This reflected perceptions that 3D printed food may be a cheap way to make food, may need less material to make a meal, and help to feed those who otherwise cannot access food (Lupton & Turner, 2018c). 3D printed food was seen as primarily applicable in situations where people have limited control and choice of their food supplies, to expand their choice, but ‘for the participants themselves, it was commonly seen as a threat to their personal choice and control over food.’ (Lupton & Turner, 2018c) p.163. A few participants (n=4) recognised the environmental and health benefits of 3D printed food based on alternative food sources. Others noted the potential usefulness of the technology in terms of decorative or novelty elements (Lupton & Turner, 2018b).

Mantihal et al. (2019) in a study of university students, staff, and visitors (sample n=244), found that two thirds of the sample were familiar with the technology and attitudes mostly positive. In terms of perceived benefits of the technology, almost all respondents (91.8%) agreed that 3D food printing can create any appealing shapes/designs, most indicated that it could create food instantly (68.4%), can be used to prepare healthy snacks (56.1%), potentially addresses swallowing dysphagia (53.7%), personalizes nutrition (57.4%), and has the potential to minimize waste (56.6%).

SRQ2 How do views differ depending on the type of technology?

Compared with other technologies:

3D printed food technology has been suggested to hold potential opportunities in the development of other novel food technologies. This would be through its ability to modify the appearance of food products which may be considered off-putting and to harness sustainable food production processes as well as sustainable products (Soares & Forkes, 2014). However, Lupton & Turner (2018b) in a qualitative study of Australian consumers, found that few participants were interested in consuming or serving 3D-printed food cultured meat or insect-based foods. In the case of insects, this was argued to be primarily motivated by the appearance and content of the 3D printed food (Lupton & Turner, 2018a). Although some participants were more likely to try the insect-based food if it looked tasty and did not obviously contain insects, for others the improved appearance did not overcome their aversion to insect-based food products (Lupton & Turner, 2018b). For 3D printed cultured meat, while some recognised the potential for it to offer 'guilt-free' meat, most were unwilling to accept it on the basis that it was 'unnatural, not fresh, not tasty, and overly processed' (Lupton & Turner, 2018b, p17).

Although different technologies were not compared empirically, Brunner et al. (2018) report that the findings of their study suggest that 'consumers' reactions toward 3D-printed food is similar to their responses to other novel food technologies that have added convenience, health-enhancing properties and a natural process as their most compelling arguments (Rollin et al., 2011)' p.395.

Attitudes towards different applications of same technology

Lupton & Turner (2018a) in their small qualitative study of Australian consumers found that willingness to consume 3D printed food and to serve it to others varied considerably across the 7 products presented in the study which included pizza, pasta, chocolates, carrots, a chicken and vegetable meal (made from purees), sugar confections, and an insect-based snack [23]. Participants were typically more comfortable with 3D printed food products which resembled actual food and familiar

[23] Between 14% and 69% of participants considered they would be willing to try 3D printed food and serve it to others depending on the product (Lupton & Turner, 2018a).

food (Lupton & Turner, 2018c). Participants were found to be more accepting of the use of 3D food printing in products considered to be already highly processed and ‘unhealthy’ (for example, chocolate, confectionary, pasta, desserts, etc), however, very few supported or could see value in using the technology to fabricate foods that are already considered ‘healthy’ and ‘natural’ such as meat, vegetables and fruit (Lupton & Turner, 2018b).

SRQ3 What shapes the public’s views?

A number of factors have been suggested to shape public views towards 3D printed food:

Appearance is reported to be a key factor in shaping responses to new food concepts (Brunner et al., 2018; Greehy et al., 2013; in Mantihal et al., 2019). Lupton & Turner (2018c) found that the appearance (the study used images) of certain 3D products could be off-putting to participants (for example, the geometric shape and white colour of insect snack or the ‘jelly-like’ chicken and vegetable meal) and contributed to 3D food products being considered unfamiliar, not obviously a food, very artificial, slimy, strange etc. These attitudes were also found to influence views on other attributes of the foods such as their anticipated texture, tastiness, willingness to consumer or serve to others (Lupton & Turner, 2018a). Despite some 3D printed foods containing natural ingredients, the strange or synthetic or artificial appearance of 3D printed food meant these were not considered ‘real’ or ‘natural’ (Lupton & Turner, 2018a,c).

Risk perceptions as a result of unfamiliarity with 3D printed food technology including the way the food is prepared and processed, the appearance and texture of resulting food, and in some cases the constituent ingredients, were a key issue for participants (Lupton & Turner, 2018b, c). This was linked to uncertainty and concerns about the safety, extent of processing, healthiness and tastiness of resulting food products (Lupton & Turner, 2018b,c).

Brunner et al. (2018) also found that lack of knowledge, along with the name of the technology (which highlights its non-food origins) contribute to cautious attitudes to this technology.

Mantihal et al. (2019) in a survey of Australian university students, staff and visitors found that knowledge and understanding of 3D printing technology was significantly related with recognition of many of the reported benefits of 3D printed food, for example, convenience, opportunity to address dysphagia, create appealing food for children, minimise food waste and so on.

Role of information: Brunner et al. (2018) provide some evidence that informing or educating consumers about the technology can significantly impact attitudes and in some cases lead to improved overall opinions towards 3D printed food. In their quantitative study those with little or no previous knowledge towards the technology were most impacted between the start and end of the survey, whereas little or no impact on skilled participants. Information presented through the survey was successful in overcoming food neophobia[24], but reinforced food technology neophobia[25], though the authors note that different approaches to information provision may be more successful.

Lupton & Turner (2018c) report that when presented with information on environmental benefits of printed food, more participants ‘expressed an environmental ethic and willingness to try this product’ (p.164), though this was primarily related to familiar foods rather than new sources such as insects. However, in a related study, the authors report that even after discussion and seeing images of examples of 3D printed food ‘little enthusiasm was expressed’ towards 3D printed food (Lupton &Turner, 2018b, p.11).

Brunner et al. (2018) conclude that first information received by consumers is important in opinion forming and that ‘well-designed communication’ has the potential to positively influence attitudes to 3D printed food.

Individual characteristics: initial positive attitudes towards 3D printed food among Swiss consumers were found to be significantly influenced by perceptions towards the technology as being 'fun to use', ‘willingness to consume’ 3D printed food, and gender; whereas negative attitudes were influenced by food technology neophobia or dislike of highly processed food, and food neophobia (Brunner et al., 2018). At the end of the survey, positive attitudes to 3D printed food influenced by perception of fun to use, willingness to consume, as well as the perceived technology benefits, and an orientation to convenience (in relation to meals), whereas negative attitudes to 3D printed food influenced by: food technology neophobia (Brunner et al., 2018).

In their qualitative study of Australian consumers, Lupton & Turner (2018a) found no real evidence that neophilia - the desire to try new foods – played a role in shaping consumer attitudes to 3D printed food products (Lupton & Turner 2018a). Likewise, perceived environmental or sustainability benefits were also not found to play strong roles in attitudes, with few participants prioritising this in everyday food choices (Lupton & Turner, 2018b). The capacity of 3D printed food technology to process alternative ingredients into food was recognised, but considered to be a potentially costly way for householders to reduce food waste (Lupton & Turner, 2018c). Few

[24] fear of eating new or alien food.
[25] rejection of the use of novel technology in food production

participants considered the benefits of novelty, personally tailored nutrition, or the potential to use fresh ingredients to prepare printed food (Lupton & Turner, 2018c).

Participants expressed concerns that 3D printed technology could already be being used to produce foods without consumers knowledge and suggested that ‘the fabricated nature of these foods should be made obvious to consumers to mark out such foods as ‘different’‘ (Lupton & Turner, 2018a, p.14).

SRQ4 Do different types of people hold different views?

Consistent with studies elsewhere (for example, Lyndhurst, 2009; Verbeke, 2005 cited in Brunner et al., 2018), both Brunner et al. (2018) and Mantihal et al. (2019) found that neither age nor education were significant in explaining attitudes towards 3D printed food; Brunner et al. (2018) also found that working status was not significant determinant. The two studies show mostly that gender is not a significant variable. Brunner et al. (2018) found gender only significant in explaining the initial attitudes of Swiss consumers, with men showing a more positive attitude than women, but not significant in explaining attitude changes at the end of the survey. Brunner et al. (2018) went on to say that their study ‘confirms that socio-demographic predictors have limited explanatory power compared to determinants related to consumers’ knowledge and behaviour’ p.395.

There is some evidence to suggest that certain personality traits may play a role in shaping attitudes towards 3D printed food, though we caution that the findings draw on just one small sample of Australians: Lupton & Turner (2018c) found that most participants that were willing to consider consuming 3D printed food considered themselves to be ‘adventurous eaters’ .

In exploring explore Australians views towards 3D printed food, Lupton & Turner (2018b) found that one-third of participants (10) considered that 3D printed cultured meat would be viewed positively by vegetarians (if not by themselves).

SRQ5 How do views affect behaviour such as food choices?

The available research on consumer acceptance of 3D printed food is hypothetical in nature. No studies were identified on actual purchasing behaviour in the marketplace.

Overall, Lupton & Turner (2018c) found little evidence that participants were willing to include 3D printed food in their everyday diets amidst other priorities and concerns. 3D food printing was ‘viewed in many respects as 'unnatural'’ (Lupton & Turner, 2018c, p.165). While the environmental and health benefits of some 3D printed foods were recognised, personal priorities in food choices tended to dominate and

3D printed food products were often seen as suitable for others rather than oneself (Lupton & Turner, 2018b). Some participants stated they would reluctantly consume 3D printed insects or cultural meat only in extreme circumstances or if there was no alternative Lupton & Turner, 2018b). In contrast, Mantihal et al. (2019) reported that most of the respondents indicated that they were willing to try the 3D printed chocolate, and that just over half of respondents were willing to have a 3D food printer at home.

One of the key challenges in consumer acceptance of 3D printed food is the lack of familiarity and understanding (Lupton & Turner, 2018a). In promoting 3D printed food to consumers, Lupton & Turner, (2018a) recommend that consideration should be given to content, the sensory qualities and level of processing. Notably, they caution that focusing on natural source food and health attributes of 3D printed foods alone are unlikely to be sufficient to persuade consumers (Lupton & Turner, 2018a). Brunner et al. (2018) further suggest that relevant aspects of 3D printed food technology to promote to consumers include fun to use, convenience, health and personalised nutrition (Brunner et al. 2018).

SRQ6 How have views changed over time?

The papers reviewed have not explored how views have changed over time, neither was this technology included in FSA’s 2009 review so there is no evidence to support a comparison.

SRQ7 What are the gaps in current research?

Additional empirical research is recommended to gain a wider and deeper understanding of consumer attitudes towards 3D printed food technology, in particular to: explore attitudes among UK consumers; further explore consumers attitudes among the general public to a range of 3D printed food with actual samples of products; to reassess the impact of food technology neophobia in a context where participants are not provided with introductory information about the technology and are provided with samples of common foods such as chocolate and other minimally processed foods (Brunner et al. 2018); explore consumer responses to different names for 3D printed foods and how best to communicate this technology to gain acceptance among consumers (Brunner et al. 2018); and to understand the factors which may influence consumers decisions to purchase 3D food printers for the home (Mantihal et al. 2019).

Conclusions/summary

- Very little research has been conducted on consumers knowledge, attitudes and acceptance towards 3D printed food (Brunner et al., 2018; Lupton & Turner, 2018a,b,c; Mantihal et al., 2019).
- Available evidence suggests that consumers in the general public tend to have low levels of knowledge and familiarity and negative attitudes towards 3D printed food technology (Brunner et al. 2018; Lupton, 2018a,b,c), though this is not universal and some sub-samples (for example, university students, staff, and visitors) have been found to be reasonably familiar and generally positive (see Mantihal et al. 2019).
- Some evidence that participants are willing to try 3D printed foods and serve it to others (Lupton & Turner, 2018a; Mantihal et al., 2019) though this varies depending on the product and does not necessarily indicate people are willing to include this technology in their daily diets amidst other priorities and concerns (Lupton & Turner, 2018c).
- Little consumer acceptance towards 3D printed cultured meat and insect-based foods despite the technology being proposed as a way to make these products more appealing to consumers (Lupton & Turner, 2018a,b).
- Views towards 3D printed food were found to be shaped by: appearance (Lupton &Turner, 2018a,b); risk perceptions (linked to unfamiliarity and uncertainty) towards safety, extent of processing, healthiness and tastiness of resulting food products (Lupton & Turner, 2018a,b,c); knowledge (Mantihal et al. 2019); information (Brunner et al. 2018, Lupton & Turner, 2018b,c), as well as individual characteristics such as perceptions towards the technology as well as food technology neophobia and food neophobia (Brunner el al. 2018).
- There is some evidence that informing or educating consumers about 3D printed food technology can significantly impact attitudes and in some cases lead to improved overall opinions (Brunner et al. 2018).
- Evidence suggests that relevant aspects of 3D printed food technology to promote to consumers include ‘fun to use’, convenience, health and personalised nutrition (Brunner et al. 2018), while consideration should also be given to food content, the sensory qualities, level of processing (Lupton & Turner, 2018a).

Synthetic biology

Key findings

- There is not a vast amount of research on consumer awareness and understanding of synthetic biology, especially to specific food applications.
- There is not a clear consensus among the reviewed literature consumer views on synthetic biology in food.
- Consumer attitudes are generally more positive towards applications with clear benefits for example, medical, energy and environment rather than for food
- Attitudes toward synthetic biology are similar to those to GM food with concerns around ‘unnaturalness’ and ‘playing God’. However, there are hopes for synthetic biology suggesting a general sense of ambivalence.
- Since 2009 there have been papers on specific applications of synthetic biology in food and as predicted views do follow some similarities to attitudes towards GM foods. However, there is still a need for longitudinal studies and more systematic studies on specific food applications of synthetic biology.

Overview of literature

This review is based on 6 papers comprising 3 reviews, 2 empirical, and one public dialogue process focussed on synthetic biology generally and specific applications in relation to food/agrifood. Of the empirical papers both were quantitative and explored consumer perceptions in Malaysia (Amin et al., 2011), and Canada (Dragojlovic and Einsiedel, 2013). The public dialogue (TNS BMRB, 2010) was run with UK members of the public. Amin et al., (2011) examined 481 Malaysian consumers perceptions of genetically modified rice that had a mice gene inserted to increase its Vitamin C content. They used Likert scales to measure five ‘ethical’ aspects (familiarity, denying benefits, religious acceptance, ethical acceptance and perceived risks). Dragojlovic and Einsiedel (2013) examined a representative sample of 1,201 Canadian members of the public view on a synthetic yeast that could produce Stevia with a focus on understanding the effects of using an ‘unnaturalness’ framing. TNS BMRB (2010) conducted a public dialogue process with 160 members of the public and stakeholder interviews on the science and issues surrounding synthetic biology in general and specifically in relation to a number of applications including food/crop applications.

Two of the review papers (Frewer, 2017; Frewer et al., 2016) discuss the way in which comparable emerging technologies, for example, pesticides (1960s); GM (1980s) have been researched largely on the back of their rejection by consumers. They argue this has led to a focus on understanding that rejection rather than understanding under what conditions the benefits of such technologies might be accepted together with a subsequent assumption by manufacturers that new technologies will be met with similar negative attitudes. However, they suggest that with respect to synthetic biology there is no clear public view at the time of writing, and what research there is suggests variability of attitudes according to context and application. In both papers there is a call to examine the perceptions of benefits of technologies. Interestingly, in the public dialogue (TNS, BMRB, 2010), revealed an ambivalence amongst participants, generally around synthetic biology – a sense of hope that synthetic biology could address some of the big issues for example, food security coupled with concerns about the potential for long term negative impacts.

Jin et al. (2019) provide a systematic review of synthetic biology applied in the agrifood sector. They looked at 24 papers, 16 were empirical and focussed on public attitudes towards synthetic biology and 8 were focussed on media reporting of synthetic biology. The papers examined came from the US and Europe.

Key topics explored across all the papers reviewed included:

- The role of 'unnaturalness' perceptions in shaping consumer views.
- Differences according to religious/spiritual beliefs.
- Similarities in views to those relating to GM.

Further, it should be noted that all the papers reviewed cite a lack of empirical research in the area of consumer views of synthetic biology across all applications. Given this, it is important not to overgeneralise any findings that are reported.

Brief explanation of what the technology is

There is no standardised definition of synthetic biology, however, 'All definitions encompass the notion that applications of synthetic biology involve the creation of novel living systems through synthesising and assembling artificial and/or natural components '(Jin et al., 2019 p.454). Definitions of the technology include:

- 'applying the engineering paradigm of systems design to biological systems in order to produce predictable and robust systems with novel functionalities that do not exist in nature' (European Commission, 2005) p.10).
- 'the design and construction of novel artificial biological pathways, organisms and devices, or the redesign of existing natural biological systems' (Royal Academy of Engineering, 2009 p.13).

- 'the design and construction of new biological parts, devices, and systems, and the redesign of existing, natural biological systems for useful purposes' (nature.com, 2019).
- 'Synthetic biology is an emerging area of science and technology, using developments in the engineering and biosciences to create new biological parts or to redesign existing ones to carry out new tasks. As one leading researcher noted – it moves us on from reading the genetic code to actually writing it' (TNS BMRB, 2010 p.14)

The technical advances of synthetic biology have led to the development of applications across a range of different sectors (healthcare, energy, environment) as well as agrifood. Within the agrifood sector, synthetic biology is considered to offer better ways to improve crops, control pests and crop diseases, enhance the environment and manage livestock. Further, as Jin et al. (2019) note 'it also has the potential to deliver advantages to novel food and food ingredient production, food processing, food safety diagnosis, food waste processing and food packaging development' p.454.

Dragojlovic and Einsiedel (2013) distinguish between top-down synthetic biology and bottom-up. The former focusses on taking genetic material and putting it into a 'platform', for example, yeast to give it biological characteristics it did not possess. The Stevia grown in yeast example in their paper is one such 'top-down' approach, together with the example of GM rice with a mice gene used by Amin et al., (2011). The 'bottom-up' approach is more ambitious and attempts to develop minimal chemical cellular life (or 'protocells') from inanimate raw ingredients.

SRQ1 What are the public's views on the technology?

Overall, there is a mixed, and rather partial picture in terms of views of synthetic biology by members of the public. There is evidence of negative views, that follow similar lines to those of GM technology, with concerns about potential environmental and human health impacts, moral, emotional or value-related issues such as 'unnaturalness', 'creating life' and 'playing God', together with increased control of technology and patents by large companies (Betten, Broerse, & Kupper, 2018; Hart Research Associates, 2013; Mandel, Braman, & Kahan, 2008 cited in Jin et al., 2019; TNS BMRB, 2011). There was also a distrust of main stakeholder groups involved - industry, government etc. revealed in some research (Betten et al., 2018 cited in Jin et al., 2019). Synthetic organisms (for example, virus, bacterium and insect), developed either for pest control or boosting plant growth raised concerns for participants about uncontrollability, unknown long-term health impacts and their potential for bioterroristic use (Steurer, 2015 cited in Jin et al., 2019). Amin et al. (2013) in their paper focused on public perceptions of GM rice containing a synthetic mice gene to enrich its Vitamin C found that the participant viewed the rice as moderately risky and they did not feel that society would be missing out on the benefits if it wasn't developed. They did not feel that GM that involved cross-species gene transfer was acceptable based on religious grounds. From the measurement of ethical acceptability in this paper it shows that overall the development of this GM rice was not acceptable to these participants. TNS BMRB (2011) found that the participants had three related aspects that contributed to their ambivalence towards synthetic biology: the tension between it being both synthetic and biological; the prospect of treating nature as components; and the potential for industrial scale production.

Jin et al., (2019) conclude, ‘At present, there are no specific issues identified from existing research which distinguish synthetic biology from other enabling technologies, in terms of public perceptions and attitudes‘ (Akin et al., 2017; Steurer, 2015 cited in Jin et al., 2019 p.463).

However, Frewer (2017) in her review paper examining historic cases of public views of emerging agrifood technologies suggests that all emerging agrifood tech will be rejected because of reactions to, for example, pesticides and GM technology. She suggests that research has focussed on why people reject these technologies rather than focussing on factors which might encourage acceptance, largely because research has followed public negative outcry against a specific technology. In citing the case of nanotechnology in particular, she shows that attitudes are not all negative, and it depends on how benefits are presented whilst acknowledging that this might change if there were to be a high profile negative case around nanotechnology applied to food. She concludes that it is not accurate to portray negative responses to technological innovation as normative across consumers, but ‘rather adoption is likely to be driven by the extent to which personal or societal benefits are perceived to results from its application, pragmatic factors to technological uptake (such as convenience of use, cost or availability), and trust in the regulatory system designed to protect people, the environment and economic functioning of society from harm’ p.696.

Jin et al. (2019) agree that ‘There is also little evidence showing an ‘inherent societal aversion’ to synthetic biology as an enabling technology (Betten et al., 2018; Pauwels, 2009)’ p.463. Rather, it is suggested that ‘that the public's actual responses/behaviour towards synthetic biology could be dependent on different contexts, such as the product type, media reportage, peer influence, risk framing and types of market interaction, rather than a rational cost and benefit assessment (Falk & Szech, 2013; Kahneman & Tversky, 2000; Oliver, 2018). Altogether, these differences highlight the need to consider a range of different factors that contribute to the context in which the technology is considered’ p.463.

Interestingly, in the synthetic biology dialogue process where participants had three days (spread over a number of weeks) to consider and debate the issues there was clear ambivalence as summarised in this quote: ‘there was conditional support for synthetic biology- while there was great enthusiasm for the possibilities of the science; there were also fears about control; who benefits; health or environmental impacts; misuse; and how to govern the science under uncertainty.’ (TNS BMRB, 2009 p.7).

SRQ2 How do views differ depending on the type of technology?

Avellaneda and Hagen (2016) cited in Frewer 2017 confirm that the factors which influence public perceptions of synthetic biology are almost identical to other enabling technologies, most notably genetic modification. Frewer (2017) in this article also suggests that there may be a different response to bottom-up synthetic biology applications from the top-down approaches. The former could become controversial if the idea of ‘creating life’ becomes central to the debate. Dragojlovic and Einsiedel (2013), report that as with GM applications, in their research, the framing that as the evolutionary distance increased between the host and genetic material the more the application was viewed as unnatural.

More specifically, Jin et al., (2019) report that views are more positive if the application of the synthetic biology was towards human health (medicine), energy and environment rather than agrifood. Further, applications may be more preferred for environmental enhancements rather than for crop improvement. The use of synthetic biology to eradicate malaria via mosquitoes was regarded positively whilst other agrifood applications, such as animals with accelerated growth and synthetic microbes applied to facilitate food production (for example, production of food additive) were viewed more negatively by research participants (Hart Research Associates, 2013, cited in Jin et al., 2019). TNS BMRB (2011) found, with respect to food and crop applications that participants were initially encouraged by the potential of synthetic biology to address issues such as food scarcity, but they also had concerns regarding who would benefit from and own the technology. In relation

Again, as with the other areas however, more research is needed to explore what views people have of different applications of synthetic biology and why.

SRQ3 What shapes the public’s views?

Some suggestion that the media may influence views, Jin et al., (2019) examined 8 papers that reviewed the media around synthetic biology and found on the whole the reportage ‘appears not to have negatively portrayed the technology in a manner that may amplify public risk perception or foster their negative attitudes’ (p.461).

Jin et al. (2019) report ‘value predispositions’ for example, religiosity, deference to authority as well as trust in scientists affects publics' views (Akin et al., 2017 cited in Jin et al., 2019). Deference towards scientific authority refers to a long term stable factor centred around the belief that the scientific enterprise is for the public good. It is found to correlate with acceptance of other technologies such as nanotechnology as well, whilst trust has been defined as the short-term and individual confidence in scientists' motivation and competency.

Dragojlovic and Einsiedel (2013), showed the impact of framing, that is, how the technology is discussed. They found that that by putting in an ‘unnaturalness objection’ into a newspaper article about synthetic biology activated that perception when the evolutionary distance is large, for example, human-yeast, but was not effective when there evolutionary distance is small for example, plant-yeast. Further, the paper discusses the fact that the framing is likely to have a different effect on people depending on their underlying values, where the unnaturalness objection taps into a value that links naturalness with goodness. ‘While this type of intrinsic valuation of nature can arise from a variety of belief systems, it is likely to be linked primarily to spiritual belief systems in which Nature is perceived to be a ‘sacred’ entity that must not be ‘interfered’ with’’ p.552 .

Overall, Dragojlovic and Einsiedel (2013), show how framing technologies in a specific way so as to highlight unnaturalness may make only people with certain values more likely to have negative perceptions of that technology. It shows that if the framing does not echo some aspect of the reality of the technology - for example, evolutionary distance indicating ‘unnaturalness’, then it is unlikely to have any effect on attitudes. For example, calling the insertion of plant genes into yeast ‘unnatural’ is unlikely to be attended to because it is deemed irrelevant to the technology in question. It shows that the picture is nuanced and that views are not held homogenously across members of the public.

Amin et al. (2011) also examined how religion related to views of synthetic biology (in this case GM rice inserted with a mice gene), finding that across all four the Hindu, Muslim, and Buddhists in their sample all considered the transfer of animal genes to a plant unacceptable in relation to their religious views, although Buddhist were more accepting than people from other religions. The main issue highlighted in Amin et al. (2011) was religious views suggesting it is a key factor in Malaysian society, and talked about unfamiliarity of the technology with a suggestion that more should be done to discuss the information and possibly to have labelling but overall not much said about what shapes the views.

SRQ4 Do different types of people hold different views?

Jin et al. (2019) suggest there is evidence for men perceiving lower risks than women from synthetic biology in a study in the US (Mandel et al., 2008 cited in Jin et al., 2019) which has been found to be similar for other technologies (Finucane et al., 2000 cited in Jin et al., 2019). However, they also say that in larger quantitative studies these differences become insignificant as has been the case with GM technologies (Akin et al., 2017; Frewer, Howard, & Shepherd, 1996; Kahan, Braman, & Mandel, 2009; Verdurme & Viaene, 2003 cited in Jin et al., 2019).

With respect to educational status, Jin et al. (2019) conclude that those with higher educational status were more likely to be supportive of synthetic biology. Amin et al. (2013) largely found no evidence of the influence of education across their five dependent variables apart from finding that those with tertiary education considered the GM rice to be more acceptable from their religious view compared to those with secondary as well as diploma or pre-university level of education.

Across the different papers, age differences in perceptions of synthetic biology and its applications are not discussed and do not appear to have been examined in depth. The exception is Amin et al., (2013) who found that 'all respondents **regardless of their age** considered GM rice as not very acceptable ethically and from their religious point of view' (p.12476, our emphases).

SRQ5 How do views affect behaviour such as food choices?

None of the papers reviewed looked at how views affect food choices, probably because there are few products available and/or known about as made by synthetic biological processes.

SRQ6 How have views changed over time?

Given the newness of the area, together with limited research, none of the papers directly examine changes in views over time. However, looking back at the FSA review from 2009, a number of aspects can be drawn out:

- There are now papers that examine consumer views of food applications of synthetic biology whereas there were none directly focussed on these applications in 2009, reflecting the growing industry in food applications of synthetic biology.
- As suggested in 2009 attitudes towards synthetic biology in general (rather than specific food applications) do seem to be similar to attitudes towards other emerging technologies, specifically GM technologies.

- However, the limited evidence that examines specific applications including food applications suggests this is nuanced, and context dependent and that care should be taken not to assume that negative views are normative.

SRQ7 What are the gaps in current research?

Overall, there is a need for more research that examines specific food related applications of synthetic biology to unpack what views are expressed under what conditions, and contexts for different types of people.

From the papers reviewed the following specific questions were highlighted:

- How do perceptions and attitudes in different demographic groups vary in relation to specific food applications of synthetic biology rather than in relation to a general description of the technology?
- How are trade-offs between benefits, risks and other issues made by people during decision-making about synthetic biology food applications?
- What are the conditions under which rhetorical frames shape how we perceive these technologies?

Conclusions/summary

- There is not a vast amount of research on consumer awareness and understanding of synthetic biology, especially to specific food applications.
- There is not a clear consensus among the reviewed literature about members of the publics' views on synthetic biology in food. Evidence suggests that consumer attitudes are generally more positive towards applications with clear benefits for example, medical, energy and environment rather than for food
- Differences in consumer attitudes between 'top-down' and 'bottom-up' synthetic biology are suggested but research has not been done to clearly show this.
- There is some evidence for the religious values impacts on attitudes towards synthetic biology, mixed findings for gender differences and little work carried out on age related differences.
- Attitudes toward synthetic biology are similar to those to GM food with concerns around 'unnaturalness' and 'playing God'. However, research also shows there are hopes for synthetic biology as well as concerns suggesting a general sense of ambivalence.
- Since 2009 there have been papers on specific applications of synthetic biology in food and as predicted views do follow some similarities to attitudes towards GM foods. However, there is still a need for longitudinal studies and more systematic studies on specific food applications of synthetic biology.

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Conclusions

Across all the technologies examined no single picture emerges of consumer views. However, there are number of key themes that seem to underlie the attitudes towards emerging food technologies which will be drawn out here together with key changes since 2009 and gaps in research. The lack of a clear picture is partly because of the inherent variability of the different technologies and the issues their development is aiming to address, partly because of the lack of systematic studies on consumer views especially in relation to specific applications of the technologies, and these conclusions should be read with those caveats in mind.

Key themes across all technologies

The themes across the technologies cover views towards the actual technology, so how the food is made, the food and the views of the potential risks and benefits of the technologies and eating food from those technologies. These are discussed as appropriate within each category. Consumer views are related to clusters of these factors, making active and dynamic decisions about foods often linked to existing cognitive models and frameworks or schema relating to foods that they are more familiar with making those views more nuanced and complex than they might seem at first.

Natural/unnaturalness

As shown in the early part of the review consumers do consider these technologies in relation to whether or not they are perceived as natural or not, with a tendency towards greater acceptance of seemingly more natural processes and products. For example, synthetic biology applications and GM food where the transfer of biological material is closer or the same as that of the host culture (for example, plant –plant) are perceived as more natural than those that cross species (for example, animal – plant). Naturalness in relation to a synthetic biology application was related to 'goodness' in terms of quality of the product. The technology for 3D printed food was seen as being a very artificial and highly processed way of preparing food. For cultured meat, nanotechnology in food, and 3D printed food many consumers felt at a personal level that these technologies are unnatural. Unnaturalness is linked to the idea of scientists 'playing God', specifically in the case of synthetic biology 'bottom-up' applications.

In terms of naturalness of products, insect eating, whilst in some cases creating a disgust reaction seem to arouse interest and potential for acceptance, perhaps because the food itself is one that is found naturally occurring, it is rather that in developed countries the tradition of eating insects is novel. 3D printed food was considered by some to be unnatural looking, for example, slimy, too perfect. Interestingly, consideration of the naturalness of, for example cultured meat, can lead to interesting discussions and realisations around the production of conventional meat, potentially blurring the boundaries between what might be considered natural or unnatural.

Controllability/uncontrollability and possibility of unforeseen consequences

Linked to the theme of natural/unnaturalness is that of controllability/uncontrollability and the potential for unforeseen consequences of technologies. In the literature, this was particularly linked to three of the technologies: GM food, nanotechnology food applications and synthetic biology food applications. Historically, this has been associated with the risks of GM crops, specifically perceptions of potentially unpredictable consequences of DNA modification which may have unseen, unintended and potentially irreversible impacts of genetic manipulation that would not occur naturally. Synthetic biology produces similar concerns as does nanotechnology to some degree. These issues were not evident in research on consumer views relating to food from cloned animals, cultured meat, or 3D printed foods.

Benefits/risks/ambivalence

Across the technologies there were perceived benefits for some of the technologies, for example health benefits of some functional foods, and the possibility of 3D foods enabling people with swallowing difficulties to be able to eat more easily. Concerns about potential health risks were linked to the uncertainty of effects of technologies and to an extent perceptions of unnaturalness. Willingness to purchase or eat these technologies was linked to a number of factors, and interestingly where price was important to people it had an impact on whether or not they would buy GM food or food from a cloned animal. Investigating the relationship between affordability and concerns about risks would be useful further research. A level of ambivalence, where people hold positive and negative attitudes simultaneously, is expressed towards synthetic biology, cultured meat and nanotechnology. Having a better understanding of whether there are key factors that dominate in consideration of acceptance of these technologies would also be useful further work.

Knowledge

There was some evidence that knowledge/information is linked with increased acceptance in some cases (for example, cultured meat; insects; GM food), but not others (for example, food from a cloned animal). Framing of information has also shown to affect attitudes towards technologies (for example, cultured meat, synthetic biology). What is interesting is for the majority of the technologies participants in the studies reviewed have low awareness or knowledge of the technologies. Studies (for example, synthetic biology dialogue) that do introduce people to more information about the technology seem to suggest that attitudes are more complex than perhaps are initially expressed. This is not to say that increased knowledge leads to acceptance of technologies, but rather that to have a clear idea of how people respond to the newer technologies having an informed public debate could be useful.

Governance

Across the technologies the issue of trust, transparency and accountability was important and linked to attitudes towards the technologies. Understanding who owns the technologies and who might benefit from them are also key factors to be further investigated.

Individual factors

The review found some limited evidence of consumers' attitudes varying in terms of:

- Gender: men more accepting/positive towards some of the technologies: cultured meat, food from a cloned animal, nanotechnology, synthetic biology and 3D printed food. Women attach more importance to the functional component of functional foods.
- Age: younger people more accepting of insect eating, cultured meat and food from a cloned animal but no effects for 3D printed food or synthetic biology. Older people more likely to buy functional foods.
- Education: higher education has some relationship to positive attitudes towards cultured meat, GM foods and food from a cloned animal, synthetic biology and nanotechnology.
- Factors such as presence of children in the household structure, cultures, country of residence, living in an urban or rural location, and other lifestyle and experience factors were found to be associated in different ways with consumer views.

Overall, however, the findings cannot be generalised given the small number of studies and the mixed findings. It does suggest that individual factors seem to be less important than perceptions of the technologies per se.

Key similarities and differences between technologies

Attitudes vary within each technology depending on the type of application and the context:

- Functional foods appear to evoke most positive attitudes especially when there is a focus on health benefits.
- Novel food processes – insect eating, whilst in some cases creating a disgust reaction, seems to arouse interest and potential for acceptance.
- Cultured meat and food from a cloned animal - findings suggest a minority of people would eat them.
- With respect to nanotechnology, there were mixed views with some research suggesting attitudes were more positive than for GM foods, but others showing that was not the case.
- GM food was largely viewed negatively, it was felt that its initial negative image has not been reduced over time although more information on benefits as well as risks has been developed.
- Attitudes to synthetic biology, in part were similar to those of GM foods but there is much less research and it varies according to application and whether the type of synthetic biology is making more (bottom-up) or less (top-down) fundamental changes to biological processes.
- Attitudes among general public towards 3D printed food tend to be negative, though this is not universal, and information had been found to improve opinions for some.

Key changes since 2009

- Research into consumer attitudes towards food from cloned animals suggests that they have not changed since 2009 and are still negative, but are now more formed than in 2009 when a large proportion of public did not have a firm view.
- Attitudes towards synthetic biology as an area of technology (rather than as applied to food) seem to be similar to those for other emerging technologies, and specifically GM technologies, and have not changed since 2009. However, the limited studies on specific food applications of synthetic biology suggest a nuanced and context dependent picture.
- Views of functional food vary depending on the combination of ‘carrier’ food and added functional ingredient. This reflects the findings in 2009, as do findings that women and older people are more favourable towards functional foods.
- Research on GM foods and consumer views has continued over the past decade, but is not as active. Views are still negative in general.

- Views of nanotechnology appear to be mixed, both negative and positive which suggests some change compared to 2009 where it was reported that awareness was low but views were generally positive.

Areas for future research

Key areas for future research across all the technologies:

- More systematic research into consumer views of specific food applications of the technologies.
- A focus on understanding how perceptions of benefits and risks associated with the technologies are changed by using different techniques for providing information and to what extent these perceptions are maintained or change in the long-term following the intervention.
- Understanding how people weigh up those risks and benefits in different scenarios would also be a useful further research focus, to understand for example, how decisions on what to buy or eat are made.
- Projects that look at actual purchasing or eating behaviours would also be useful as current work is all hypothetical in terms of behaviours.
- Longitudinal research on consumer views across most of these areas to understand change over time and the impact of familiarity/context.
- Finally, understanding how people see the relationships between these technologies would be useful as that could help understand how new technologies with similar characteristics might be viewed in the future.

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Annex

This annex provides further information about the method adopted for the REA.

REA protocol

The REA protocol describes how the REA was carried out, focussing on the inclusion/exclusion criteria, search string, sources of evidence and approach to prioritisation of documents. As far as possible we aimed to use the same approach to that used in 2009. We have highlighted where there are differences and provided a rationale for any changes. The draft protocol follows the structure laid out in the Defra/NERC guidance on the production of quick scoping reviews and rapid evidence assessments (Collins et al., 2015).

Research Question(s)

The Primary Research question for the project is: **What are consumers' views of emerging food technologies, how have these changed over the last decade and what insights might we glean from this to inform future policy?**

To further clarify the research question we used the PICO approach which details which population is to be studied, what the intervention is that we are looking at, what comparators we are interested in and what outcomes we are investigating (Table A1. 1). The research question is a non-impact question, i.e. 'What is the evidence surrounding?' rather than a question about specific interventions.

Table A1. 1. PICO factors

PICO factor	In this research
Population	UK food consumers
Intervention	Emerging food technologies
Comparator	How have these changed over the last decade, that is, compared with attitudes and behaviours before 2010? How do views differ depending on the type of technology? How do attitudes towards the different nine types of technologies compare with each other? Do different types of people hold different views? How do views compare across different groups of people, based on characteristics such as age, gender or socio-economic background.

PICO factor	In this research
Outcome	Insights for future policy

There are eight sub-questions:

- SRQ1 What are the public's views on emerging food technologies?
- SRQ2 How do views differ depending on the type of technology?
- SRQ3 What shapes the public's views?
- SRQ4 Do different types of people hold different views?
- SRQ5 How do views affect behaviour such as food choices?
- SRQ6 How have views changed over time?
- SRQ7 What are the gaps in current research?

Scope

The scope established the inclusion criteria/exclusion criteria for our search strategy (Table A1. 2). We used the same inclusion/exclusion criteria as the project in 2009.

Table A1. 2. Exclusion and inclusion criteria used in the search for literature.

Exclusion criteria	Comment
Exclude studies not in English	
Exclude any research that is not relevant to food.	
Exclude research that doesn't address consumer views.	i.e. if it is about the technology only, discard it.
Exclude newspaper articles but explore any report references cited in the article.	Key opinion articles that are found will be kept as they could form stimuli for the dialogue workshops
Inclusion criteria	**Comment**
Include worldwide	
Include literature from 2010 onwards.	
Include any method.	Includes review articles as well as empirical studies.
Include peer-reviewed research and grey literature.	Note in the report the quality of research used as evidence (including whether it has been peer reviewed/ published in a journal).
Include literature on all/any of the	Includes:

nine identified emerging food technologies.	• lab grown meat • food where nanotechnology has been used • food that has been 3D printed • food that has been genetically modified • food from a cloned animal • novel food processes • functional food • synthetic biology

Process of prioritisation

Only the most pertinent articles were reviewed in full. To facilitate this process, each source was evaluated in relation to the prioritisation criteria:

- The extent to which the source was directly relevant to one or more of the eight research questions. Expert judgement was used to evaluate this
- The quality of the source. Each source was described in relation to:
    - Whether or not it was peer reviewed
    - Number of citations
    - Journal impact factor
    - Quality/robustness of the conclusions, for example, were they backed by good data/findings
    - Whether or not limitations of data & quality were discussed

Key words used in the search

Table A1. 3. Key words used in the search for literature (trialled to establish the number of hits)

PICO factor	Keywords
Population	Consumer; public; society; individual;
Intervention	Technology words for example, lab grown meat; cultured meat; clean meat; irradiated food; irradiation; nanotechnology; 3D printed food; GM food; genetically modified food; genetically engineered food; cloned animal; animal cloning; novel food processes; emerging technologies; functional food; synthetic biology;
Comparator	Attitudes; behaviours; views; perceptions; awareness; opinion; acceptance; actions; habits;
Outcome	N/A
Other relevant keywords	UK; food; changes; differences;

The following search strings were used in the Scopus search:

1. (**Consumer*** OR **public** OR **society** OR **individual***) AND (**attitude*** OR **behaviour*** OR **view*** OR **perception*** OR **awareness** OR **opinion*** OR **acceptance** OR **action*** OR **habit***) AND **food*** AND (*insert food technology search terms*) AND (**chang*** OR **difference***)

2. (**Consumer*** OR **public** OR **society** OR **individual***) AND (**attitude*** OR **behaviour*** OR **view*** OR **perception*** OR **awareness** OR **opinion*** OR **acceptance** OR **action*** OR **habit***) AND **food*** AND (*insert food technology search terms*)

The search string was edited for each technology by inserting the following search terms:

- "**lab grown meat"** OR "**clean meat"** OR **"cultured meat"** OR "**in Vitro meat**"
- "**3D print*"**
- **nanotechnology***
- (**GM** OR "**genetically modified**" OR "**genetically engineered**")
- ("**cloned animal**" OR "**animal cloning**")
- "**novel food process***"
- "**functional food**"
- "**synthetic biology**"
- "**emerging technology***"

Source locations

Locations for peer reviewed evidence (for example, bibliographical databases)	Scopus
Locations for grey literature (for example, websites of key organisations)	Google (which scans grey, government and commercial sources) The ESRC genomics network website (archived 2014 but still may have useful content) The Project on Emerging Nanotechnologies website Institute for Food Science and Technology (IFST) website

	Oxford Martin Programme on the Future of Food website Horizon 2020 website Commercial research company websites (Ipsos MORI, Gallup, NatCan, Opinion, Leader, BMRB) Interested group websites (for example, Friends of the Earth, Greenpeace, Demos) International Risk Governance Council website.
Locations for unpublished data	Key experts; research council websites; and EU research.
Will other reviews and secondary reviews be considered?	Yes
Will theoretical or conceptual studies be considered?	No

Expert interviews

Additionally, eight experts responded to our call for information regarding evidence on consumer attitudes towards emerging food technologies, either participating in interview (n=6) or providing information, such as literature recommendations, via email (n=2). This included experts from academia and industry.

Literature for review

Table A1. 4 sets out the total number of papers identified at each stage of the review process and the number included in the final review for each technology.

Table A1. 4. Summary of literature reviewed for each technology and as identified at each stage of the REA process. Numbers in brackets in the second column denote the number of search results when the search string did not include '(change* OR difference*)'.

	Scopus Search	Scoping – Literature meeting exclusion criteria	Grey literature search	Expert recommended literature	Literature meeting the prioritisation criteria	Final list of literature reviewed
Cultured meat	18	15	8	12	Yes = 11 Yes (recommended) = 12 Possible = 2	Total = 23 (review = 9 empirical = 14)
3D printed foods	5 (7)	6	0	5	Yes = 3 Yes (recommended) = 3	Total = 6 (empirical = 5 Conference paper = 1)
Nanotechnology	41	22	1	8	Yes = 13 Yes (recommended) = 3 Possible = 7	Total = 10 (reviews = 5 empirical = 5) Not reviewed = 13
GM food	200	72	1	9	Yes = 16 Yes (recommended) = 4 Possible = 16	Total = 11 (review = 10 empirical = 5 mixed = 3) Not reviewed = 9
Food from a cloned animal	4 (10)	10	1	0	Yes = 7 Possible = 2	Total = 9 (reviews = 3 empirical = 5 position paper = 1)
Novel food processes	3 (8)	1	0	17	Yes (recommended) = 17	Total = 17 (reviews= 4 Book chapters = 3 Empirical = 9)

	Scopus Search	Scoping – Literature meeting exclusion criteria	Grey literature search	Expert recommended literature	Literature meeting the prioritisation criteria	Final list of literature reviewed
Functional food	201	44	1	1	Yes = 22 Yes (recommended) = 1 Possible = 10	Total = 11 (reviews = 3 empirical = 8) Not reviewed = 12
Synthetic biology	3 (24)	3	1	2	Yes = 3 Yes (recommended) = 2 Possible = 1	Total = 6 (reviews = 3 Empirical = 2 Public dialogue process = 1)
Emerging technologies/general	17	5	12	4	Yes = 1 Possible = 2	Total = 0 (All duplicates/reviewed for other technologies)
Total results	**526**	**178**	**25**	**58**	**YES = 115 POSSIBLES = 40**	**93**