

How natural is our food?

How relevant is that word for the design of future food?

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Abstract

Ever since we were hunter-gatherers, we have learnt from nature to produce food increasingly efficiently. Hunter-gatherers collect their food directly from nature; we currently get our food from agriculture and domesticated crops and animals with significantly changed DNA, and more or less complex production and processing steps.

Even though food production and products are increasingly distant from nature, consumers have strong positive perceptions about 'natural' when it relates to food. This perception of naturalness is widely used in food marketing, but has also reached formal policies and regulation. Ethical debates are ongoing about soilless horticulture, genome editing and processed food, leading to various dilemmas. Where do we draw the line of 'naturalness' now, and how will that affect the future of our food? There is a complex relationship between the perception of 'natural' and the terms 'healthy' and 'sustainable'.

When looking at our food and how it is designed, it would be interesting to see how the definition of 'naturalness' evolves in the future. We conclude in our analysis that there is either no such thing as truly natural food, or that all our food is intrinsically natural since it is all derived from nature and natural processes. However, 'technology' often has a negative connotation when connected to food. Future food trends may need to take this perception of naturalness into account, but in the absence of clear definitions, the dilemmas will continue to create space for innovations.

9.1 Defining 'naturalness'

For most people 'naturalness' is a highly appreciated characteristic of many goods and food in particular, as exquisitely featured by the title of Allan Holland's paper: 'Nature – every drop of it – is Good' (Holland, 1996). It is deeply engrained in human psychology (Li and Chapman, 2012, Moscato and Machin, 2018, Román *et al.*, 2017). It particularly features in the context of food, such as in the discussions about genetic modification (Morris, 2001) and additives (Marley and Chambers, 2019). In the public perception there seems to be an intrinsic link between the terms 'natural' and 'healthy and sustainable', which makes it an important term in food marketing; however, without a proper definition it is bound to create confusion (Ferris, 2010).

The use of the term is therefore relevant, both in terms of ethics and in the future design of our food. The term ‘Natural foods’ is relevant to consumers, yet, like the term ‘green products’ (Durif *et al.*, 2010), it frustrates producers due to the lack of a formal definition of ‘natural’ or the even less delineated term ‘green’.

The terms ‘natural’ or ‘naturalness’ are not as straightforward as they may sound. Dictionaries show a wide range of meanings, from usual, spontaneous, untreated, to spontaneous and biological.

Dictionaries makes it clear that ‘naturalness’ is best explained when including an antonym: ‘the degree to which something appears to be natural rather than man-made’ (MacMillan¹), or Webster Dictionary: ‘occurring in conformity with the ordinary course of nature: not marvelous or supernatural’ (Webster²), or ‘as found in nature ...’, or ‘from nature; not artificial or involving anything made or caused by people’ (Cambridge³). The term is thus described through the antonym ‘contrived’, meaning artificial, manufactured, engineered and planned.

There are distinct differences in the perception of ‘naturalness’ when applied to food and medicines (Rozin *et al.*, 2004). When applied to food, the word ‘natural’ is commonly only connected to post-harvest operations: ‘food that has undergone minimal processing and contains no preservatives or artificial additives’,⁴ or ‘food that has had little processing (= preparation, change, or treatment of food) and nothing added to it.’⁵

perception

In a wide range of debates, however, the term naturalness is currently used in a much wider context, i.e. not just the state of the food itself (processing, additives), but also relating to the way it is produced. This opens up the use of the wide range of synonyms and antonyms of ‘naturalness’. In this chapter, we analyse the current ‘naturalness’ of our food and relate it to the trends and technical developments that are shaping our food and that will continue to do so in the future.

9.1.1 *The origins of our food*

Food supply is a basic prerequisite of all living species, including humans. Food sources shape the evolution of species to a significant extent. Humans developed into omnivores either by want or necessity and must have tested a wide diversity of natural products by trial and error for their palatability and possible toxicity creating a significant knowledge base that had to be transferred throughout generations. Such knowledge about food was largely communal, whereas medicinal knowledge was transferred from individual to individual successor in most cultures. Hunter-gatherers had to deal with the seasonality of many food stuffs. In nature,

1 <https://www.macmillandictionary.com/dictionary/british/naturalness> (accessed 1 July 2023).

2 <https://www.merriam-webster.com/dictionary/natural> (accessed 1 July 2023).

3 <https://dictionary.cambridge.org/dictionary/english/natural> (accessed 1 July 2023).

4 <https://www.merriam-webster.com/dictionary/natural%20food> (accessed 1 July 2023).

5 <https://dictionary.cambridge.org/dictionary/english/natural-food> (accessed 1 July 2023).

berries, nuts, roots, grains and game are not always available and despite romantic ideas about forest or nomadic life, food shortages must have been quite common at times.

domes-
tication

Farmers started to domesticate crops based on the products that they used to collect. They used their gradually increasing knowledge about soils, water, and plant diseases to adapt their natural environment as well as the plants and animals themselves, forcing humans to settle close to their crop production fields. This led Harari (2014) to suggest that early humans did not domesticate their crops, but rather that the crops domesticated humans, i.e. led them to adopt a sedentary life in permanent houses (*domus*) (Harari, 2014). This co-evolution of farming and social organization of humans has continued over the past millennia at increasing speed. Preserving and storing food creates more and more refined – in both meanings of the word – food for the increasing human population. Pickled cucumbers, salted herrings, cooked and sealed red beet and many more examples create food that can be consumed during the hunger season and that tastes different from the fresh product. The grinding of grains for baking bread or brewing beer was a food processing technique already applied before farming was ‘invented’ (Diamond, 1997; Harari, 2014).

Our food is thus, both in terms of the method of production and the content of the food itself, based on nature, but increasingly distant from it.

9.1.2 *Food production: learning from nature*

Food is of paramount importance for survival. Humanity has evolved because of its capacity to learn from nature and use that knowledge to transform the natural resources and environment to serve its needs. That transformation has been going on at least since the dawn of agriculture some 11,000 years ago. Concerns focused for a long time on household and community food security and innovations to adapt to new conditions when communities migrated. Gradually, and notably from the 1960s onwards, concerns increased with the complexity of food systems, including emerging risks associated with environmental degradation, geopolitical dependencies and climate change. Morality, which has always played an important role in food, in history through taboos and religion, is claiming an increasingly important role in debates about the future of our food. Perceptions of naturalness are an important issue in this respect.

Learning from nature has always been the driving factor behind innovation in our food production systems and our food itself. Learning that harvesting, selecting and replanting seeds gradually produced better crops, with plump grains that don't shed like the ancestors of the crops in natural conditions, that grow better when other plants (weeds) are removed, and that taste better than their often bitter or even toxic relatives. This ‘domestication’ has produced in various locations and moments in history different crops and uses. For example, humans in the Fertile Crescent gave us barley, wheat and lentils; in Latin America potato, beans, tomato,

maize, cassava and cocoa; and in China rice and soybean. Africa is the home of oil palm, coffee and sorghum. Such domestication continues until the present day. (Østerberg *et al.*, 2017).

Also, in terms of production we have increasingly used concepts of nature in order to move crop production systems away from actual natural ecologies. A major development in agronomy followed after Justus von Liebig who identified the chemical needs of plants in 1840, leading to the development of chemical fertilizers and eventually to soilless horticulture using rockwool or just water as substrate. Covering vegetable crops with glass to protect seedlings in spring has developed into computerized greenhouses and vertical farming under artificial lighting that fully recirculate water and where reared antagonists control plant pests.

agronomy

Chemical pest control has a very long history of protecting crops against pests and diseases. The use of sulphur dates back some 4500 years. Plant-based insecticides, such as Derris and Pyrethrum, were identified around 1750, followed by many others (Hikal *et al.*, 2017) and were largely replaced in the late 20th century by chemically produced pesticides. Biological pest control obtained by releasing enemies of the pest started in the late 19th century with the introduction of the Vedalia beetle *Rodolia cardinalis* from Australia to control cottony cushion scale in the USA.⁶ This is now a multimillion-dollar industry, rearing insects, parasitic nematodes and micro-organisms to ensure that several crops can now be grown in greenhouses without the use of any other crop protection measures but natural enemies of the major pests.

chemical
pest controlbiological pest
control

Important lessons from nature affecting the evolution of how our crops themselves were drawn by Camerarius (1694), who proved sexuality in plants which started an understanding of cross-breeding, by Mendel (1864) who formulated the laws on heredity which spurred scientific plant breeding, and Watson and Crick (1952) who described the structure of DNA. Many others identified novel uses of these and other basic concepts, which is now the basis of a thriving plant breeding sector using genetics, a variety of DNA techniques and big data/artificial intelligence to support plant breeding, i.e. in the creation of diversity and selecting from that diversity. Over the millennia, crops have changed in such ways that consumers would hardly be able to recognize the species from which they were originally derived; not just Teosinte developing into maize, and the grasses that created our cereals, but also the cabbage family with its many uses, and the tiny Mexican berries that we now call tomatoes.

crops

So, agriculture itself developed through subsequent steps in learning from nature and applying such knowledge effectively for the benefit of food production. Does this make our food unnatural? Is there a line that we crossed? Did we cross this when we started planting seeds and tending our gardens, or when we changed our

6 <https://ipm.ucanr.edu/agriculture/citrus/cottony-cushion-scale/>.

crops (and animals) in such a way that they would not survive without human care? Let's look at it in more detail.

9.1.3 *Dilemmas in agronomy with regard to naturalness*

The term 'natural' creates a wide range of dilemmas when applied to food production, especially when 'natural' is equated with 'good' and 'sustainable'.

copper sulphate

The use of copper sulphate, a naturally occurring chemical, in crop protection (Tamm *et al.*, 2022) is very effective against a range of plant pathogens, for example in grapes. But despite its 'naturalness', and on that basis approved in organic wine production, it is clearly not the most environmentally friendly compound as heavy metals like copper easily accumulate in the soil.

pyrethrum

The naturalness of 'pyrethrum' may also be a cause for debate, since the insecticide may be harvested from flowers in Kenya and is used way outside the context of its natural presence in intensive agriculture all over the world. The next question is whether the chemically produced pyrethrum compound can be considered as natural as the same chemical product extracted from plants, or whether a chemical derivative of the compound selected for improved effectiveness can still be considered 'natural'. Taking this dilemma to a more extreme form is the use of the insecticidal property of *Bacillus thuringiensis*, a bacterium that is quite common in many soils (de Maagd, 2015). It can be applied to crops directly from the soil or selected and purified to improve efficacy as a commercial spray. The same insecticidal property of the bacterium may also be introduced in the DNA of crops through transgenesis, i.e. genetic engineering.

crop production

That 'naturalness' creates some dilemmas in terms of sustainability and may also be illustrated by the substrates we use in crop production. The use of soil as substrate is prescribed by the rules of organic agriculture in Europe (EU, 2018). Other substrates like rockwool, hydroponics and aquaponics (Friscella *et al.*, 2021) can have clear sustainability advantages as they can prevent damage by soil-borne diseases and pests in greenhouse horticulture without the use of pesticides. They can also reduce the use of the soil-improver peat, a substrate that is harvested from nature at a rate that is unsustainable in several source-countries.

So unnatural substrates for crop production can have sustainability advantages, and some plant-based crop protection products can have clear sustainability challenges. Agriculture is either not natural, because it involves a wide range of human interventions, or it is all natural, because all interventions are based on learning from nature. And the relationship between naturalness and sustainability is dubious. How do we explain the phrase 'Nature – every drop of it – is good' from the introduction of this paper?

9.1.4 *Dilemmas in plant breeding with regard to naturalness*

breeders

Throughout history, farmers and breeders have adapted crops to their needs, initially through selection only. Breeders then found a variety of ways to find and create diversity to select from:

- Introduction of diversity from other regions to cross it with the local gene pool (from ca. 1800), something that would not happen in nature (Louwaars and Burgaud, 2016);
- The use of the natural concept of heterosis by creating hybrids using controlled crossing of selected parent lines in 1925 (Duvick, 2001);
- The use of mutagenesis using ionizing radiation as a way to create diversity in the 1920s (Stadler, 1928; Kharwal, 2012);
- Duplication of the number of chromosomes with natural colchicine in the late 1930s (Eigsti, 1938);
- Chemical mutagenesis on plants/tissues and in cell cultures in the 1940s (Auerback and Robson, 1944);
- Embryo rescue, preventing abortion in interspecific crosses in the 1950s (Nitsch, 1951);
- Tissue culture techniques for quick propagation which took off in the 1960s (Murashige and Skoog, 1962);
- Doubled haploids using cultured gametes to accelerate homozygosity since the early 1970s (Kasha, 1974);
- Cell fusion and protoplast fusion with the aim of combining genomes in the 1970s (Carlsen and Smith 1972);
- Transgenesis: the transfer of functional genes from one species to another in the 1980s (Herrera-Estrella *et al.*, 1983), which some claim is not unnatural (Wickel and Li, 2019);
- Molecular marker-assisted selection in the late 1980s (Paterson *et al.*, 1988);
- Cisgenesis: the transfer of functional genes within (or between crossable) species in the 2000s (Jacobsen and Schouten, 2007);
- Targeted mutagenesis: the targeted cutting and/or replacement of base pairs (ZFN, TALEN) (Shukla *et al.*, 2009) and techniques based on Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR-Cas) (Jinek *et al.*, 2012);
- Genomic selection (Nakaya and Isobe, 2012) increasingly supported by artificial intelligence to analyse big data.

All these methods require human intervention, so in the strictest sense will not yield ‘natural’ products in the ‘Cambridge definition’ above. Crossing plants from different origins requires a person to bring them together so is not something that would easily happen in nature.

When we consider all inventions that are created by observing natural phenomena and using that knowledge in novel ways, then all the above could be considered ‘natural’. CRISPR-Cas was developed by observing that certain DNA sites in bacteria (van der Oost *et al.*, 2009), the Clustered Regularly Interspaced Repeats, are in fact a library of identifiers of viruses that the bacterium uses to quickly respond to a virus attack, followed by its capacity to cut and destroy them. That knowledge can now incite targeted mutations in higher organisms due to faults created by the natural repair mechanism, or guide such repairs thereby intentionally creating more specific alterations. So it is highly technological but is based on knowledge

of the natural processes. Still, in focus groups ‘perceived naturalness was found to be the main reason for obtaining different levels of acceptance, not only between gene-editing and genetic modification but across all breeding techniques examined’ (Nales, 2023). There are different perceptions with respect to levels of unnaturalness (Rozin, 2005) among such breeding processes. The fact that all these methods are derived from ‘learning from nature’ does not preclude value judgements.

9.1.5 *Dilemmas in food processing*

The term ‘natural food’ is most commonly used in terms of aspects of food processing (Chambers *et al.*, 2018, Evans *et al.*, 2010). The most extreme opponents of processing are the followers of the concept of raw foodism, which when fully implemented carries a range of health issues (Runn, 2007). Apart from raw vegetables, and in some cultures raw fish and meat, all our food is cooked, fried or otherwise processed and therefore may not be considered inherently unnatural.

factory-
processed food

The claim of unnaturalness is commonly related to factory-processed food – refined white sugar as opposed to honey or less refined brown sugar, and constituted food like cookies, soft drinks and tinned soup. In factories, individual constituents like proteins, oils or sugars may be added, as well as preservatives, and taste and colouring compounds, which could be ‘natural’, e.g. colouring from berries, or chemically produced copies of natural compounds such as ascorbic acid (vitamin C). Also here, clear lines are difficult to draw and dilemmas occur (Aschemann-Witzel *et al.*, 2019) when consumers want to choose on the basis of their ‘naturalness’ evaluation (Battacchi *et al.*, 2020). Marketeers know the importance of packaging in this consumer assessment (Binninger, 2017).

meat
replacement
products

An example is vegetarian meat replacement products whereby there is no animal suffering, but which are highly processed. Of course, consumers may also choose the less processed plant products which don’t have a ‘meat-like’ structure and which require some more work to prepare in the kitchen. The replacement is less easy with vegetarian ‘milk’, processed from almonds, oats or other products, especially when vitamins and minerals are to be added to make it more comparable to dairy. Concerns about such ‘processed food’ are thus weighed against animal welfare and sustainability. One other concern of vegetarian users of such ‘milk’ is that the press cake that is left at the end of the production process is used as feed in the animal production industry.

biotechnology

The use of preservatives reduces food waste, which is an important sustainability issue. Vinegar, sugar and salt may be considered natural preservatives though. Interestingly, there is little debate about the use of biotechnology in food processing, genetically changed microorganisms that are used in cheese making, beer brewing and all kinds of fermentation processes.

9.1.6 *More or less natural?*

So, all our food is natural, or all of it is totally unnatural. The crops we eat do not look like the natural plants that they were derived from through intentional and

often highly technical human interference, so our food is not natural. Our plants and animals were derived from nature and were changed through breeding processes that humans learnt from nature, so our food is clearly not unnatural (artificial). Our plants are grown in highly controlled conditions, with a lot of human interference in soil preparation, weeding, and pest control, using increasingly complex and computerized machines, but all agronomy is based on studying nature. Most of our food is processed at home or in increasingly complex factories using heat, fermentation and other technologies, which are to a very large extent based on learning from nature. Attempts to integrate the different 'naturalness' components in one system, the Food Naturalness Index' (Sanchez-Siles, *et al.* 2019) have not yet been rolled out on a large scale.

So, drawing a clear line under what which we could call 'quite natural' is difficult, especially for scientists. Ethics can support the drawing of such lines as shown by the biotechnology debates (Louwaars and Jochemsen, 2021). The organic movement, originating from an environmental perspective banning chemical fertilizers and crop protection products, currently puts Health, Ecology, Fairness, and Care' at the centre of its philosophy,⁷ based on the views of the Biodynamic (brand name Demeter) sector, 'a holistic, ecological, and ethical approach to farming, gardening, food, and nutrition, rooted in the work of philosopher and scientist Dr Rudolf Steiner, whose 1924 lectures to farmers opened a new way to integrate scientific understanding with a recognition of spirit in nature.'⁸

ethics

Based on the 'care' principle and the 'partner of nature' perspective of this movement, the intrinsic value of the organism (and the cell) is considered important. Extensive discussions in organic and bio-organic circles (Wilbois *et al.*, 2012) formally resulted (IFOAM, 2017) in the adoption of the concept that breeding methods where humans interfere in(!) the cell to change the DNA are not compatible with organic principles and values. These include cell fusion and mutation breeding, and any products of 'genetic engineering'. Marker-assisted selection and genomic selection are welcomed though as these techniques do not alter the plant (IFOAM, 2017). The biodynamic movement also opposes the use of hybrids, even though the word 'natural' or 'naturalness' is rarely used in their communication.

Consumers seem to understand that organic *and biodynamic* food is more natural (Hemmerling *et al.*, 2016), healthier (Siipi, 2013; Lusk, 2019) and more sustainable, but all these three components are so complex that such claims cannot be made across the board, as shown in previous sections in this paper (Amos *et al.*, 2014, 2019).

On the other hand, some religious groups approve of such breeding techniques as long as the species barriers are not crossed (Jochemsen, 2000, 2008), and environmental groups (Greenpeace, 2021) see benefits in using such laboratory techniques, but only for selection purposes. The European Group on Ethics in Science

7 <https://www.ifoam.bio/>.

8 <https://www.biodynamics.com/what-is-biodynamics> (accessed 1 July 2023).

and New Technologies (European Commission, 2021) sees few ethical concerns in the application of genome editing in farm animals or plants, but they do identify possible socio-economic concerns with regard to their potential to change the structure of the breeding sector and farming as such.

culture

The ‘culture’ perspective exists alongside the above ethical perspectives. This may be linked to the values of ‘local-for-local’ principles supporting both local food culture and reducing excessive transport of food products, as exemplified by for example the ‘slow food movement’ (Schneider, 2008). Also here, some dilemmas appear with respect to sustainability (when products can more efficiently be produced elsewhere) and ethics, as identified above. What if, for example, the Sangiovese grape can be ‘saved’ by making it resistant to diseases and tolerant to drought using genome editing? Local food culture is gaining importance in certain groups in the population, opposing globalized pasta, burgers and fries, and some welcome and others loathe the internationalized curries and rice dishes in the diversity of exotic restaurants on offer. Local-for-local does not necessarily link to local food culture though. When will quinoa, grown in the Dutch polders, become part of the Dutch food culture, in the same way as tomatoes which also originate from Latin America have become a key component of Italian cuisine?

Both the globalization of food culture, and the emergence of a range of concepts like natural, sustainable and organic, have multiplied the food choice for consumers, notably for those that have the financial means to choose.

9.2 The future of food and the choices and dilemmas for consumers

Technological developments, demographic and global dependencies will continue to change food habits and food choices. How the perception of naturalness will play out with cultured meat (Siegrist and Sütterlin, 2017), with food made of products produced by algae, or with any innovations in food processing, cultivation and reproductive material, is an important question for the designers of new foods.

There is proof that the arguments around the concept of ‘naturalness’ play a role in public debates and in policy and regulation. Such arguments play an important role in policy debates about genetic engineering (currently notably genome editing and *ci*-genesis), about pesticides (how will ‘green crop protection products’ be assessed?) and about alternative production and processing methods (the Italian Government suggests banning cultured meat on the basis of food culture arguments). The regulators may be guided by their specialists in ethics after the food safety assessments under the rules and procedures of Novel Food (in the EU⁹) have been cleared. Differences in perception among countries (Rozin *et al.*, 2012) may thus influence regulatory decisions.

⁹ https://food.ec.europa.eu/safety/novel-food_en.

Apart from regulation, consumer behaviour will also be important for the success of foods produced in novel ways (Lusk *et al.*, 2014). Will cultured meat be considered natural enough because it is created with ‘real’ animal cells rather than extrusion, recombination technologies including a wide range of additives to create vegetarian meat? Will the opposition to calling vegetarian meat-replacement products ‘meat’ also apply to such products?

consumer
behaviour

Akin *et al.* (2019) claim that there are spillover effects of ‘earlier’ debates on food and food technologies, such as GMO to future ones (in their case nano, but equally relevant for other novel foods), so all aspects of the debates need to be taken into account.

9.2.1 *Neophobia*

Neophobia, the strong psychological resistance to new things is coined in the debate, setting known (natural) products against novel ones (Siipi, 2013, Siegrist and Hartmann, 2020). Neophobia is analysed as either a personality trait (Pliner and Hobden, 1992) or a state, measured in food preference tests (Hobden and Pliner, 1995). In a review study, Rabadán and Barnabéu (2021) conclude that a downward trend over time in the level of food neophobia is in general connected to increased education, income and urbanization. They do consider food neophobia as a key variable in adoption of new foods (e.g. genetically modified foods) or novel food production techniques (e.g. nanotechnology).

9.2.2 *Justice and trust*

Neophobia is certainly not the only reason for opposition to new technologies and new types of food. Uncertainties about technologies themselves (‘opening Pandora’s box’), lack of participation (‘kept in the dark’) and questions about who will use and benefit from the technologies (the rich?, large corporations?) are arguments that have played a role, next to health concerns in the debate on radiation of food in the 1990s (Roberts, 2014; Degreef, 2018) and nanotechnology this century (Davies *et al.*, 2010), and indeed in genetic modification. So, naturalness is not the only aspect determining acceptance or rejection of a new food technology.

This objection to ‘going against nature’ reflects “wider unease about science, about technological modernity, and about hubris.” (Macnaghten, 2014). While Siegrist and Sütterlin (2017) point out the ‘trait’ aspect of neophobia such that ‘consumers rely on symbolic information when evaluating foods, which may lead to biased judgments and decisions’ (Siegrist and Sütterlin, 2017), natural science arguments are not the only reason why people adopt or reject our future foods.

9.2.3 *Balancing act for consumers*

Apart from deep psychological opposition to new foods, consumers are given the complex choice of balancing their conflicting interests. Roman *et al.* (2017) point to the interest consumers have in saving cooking time (convenience food) and at the

conflicting
interests

same time avoiding processed food. Siipi (2013) focuses on the dilemma of cultured meat, which can be considered environmentally and animal friendly. Discussions about whether 'organic' is a sustainability concept or basically an ethical concept that foregoes certain environmental sustainability options, contribute to the complexity of making 'the right' choice.

The marketing concept of 'green' products may facilitate such choices compared to 'natural', as it is understood to combine different components of the 'positive choice'. Choosing 'green' not only gives a positive feeling to the consumer (Maniatis, 2016), but also triggers positive social behaviour (Mazar and Zhong, 2010). For example, Cavaliere and Ventura (2018) found that the use of (any) technology to increase the shelf life of products was rejected by many respondents despite the clear sustainability benefit. Also here, the lack of definition and the resulting possibilities for using the term 'greenwashing' creates different responses among consumers (Durif *et al.*, 2010).

9.3 Conclusion

Past experiences do provide important information about the future foods that will enter the market. Food is never totally natural or unnatural. Consumer choices depend on their knowledge but also on socio-cultural values, and in the end different and often competing individual and collective values and goals compete for priority. A complicating factor in the analysis is that most consumer research is done on the perception of 'natural' and 'green' products, and not on actual buying behaviour (Bravo *et al.*, 2022; Barbu *et al.*, 2022).

Developers and designers of new products or products made with new processing technologies, growing or genetic technologies, start with a challenge. New technology in food is hardly ever a buying argument, in contrast to new technologies in cell phones, cars or medicines. This means that the extra benefits need to outweigh the natural reluctance of the average consumer. Sustainability may be an important argument, or animal welfare, or price.

Another important argument is that 'naturalness' is an important concept despite its unclear definition, but that other arguments can become dealbreakers. Who owns the technology, who benefits? Do we understand (the need for) the technology, and are suppliers transparent? Can we follow the ethics surrounding the technology? Food is special: we are comfortable with all kinds of biotechnology in medicine and allow doctors to inject them directly into our body; we are also comfortable with the biotechnology producing our beer and bread. But many people have a problem when the term DNA comes into play in discussions about our food and arguments that nature shuffles, breaks and moves DNA. The fact that we have been doing this for a hundred years or so is not convincing. It is not the product that counts but the way it has come about, as Otsuka (2021) found in genome

editing discussions. The term ‘natural’ can mean many things – it can both support and frustrate innovation. Marketeers have identified the value of the term – for scientists it is too ill-defined to be used. A general conclusion of this study was already formulated many years ago by Levy Strauss:

the selection of foods is made not only on physiological requirements, perceptual and cognitive mechanisms, but also on the basis of cultural and social representations, that result in additional constraints on what can and cannot be eaten, what is liked and what is disliked.’ As Strauss puts it: ‘things must not only be good to eat but also good to think. (Fischler, 1980)

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