HOW TO FEED THE MONSTER

Can Technology Restore The Balance In The Food Chain?

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Abstract

In this essay, the main focus is on the question whether the Food & Agri industry should leverage technology in general, and CRISPR-Cas9 in particular, to drive the big change needed; the change of humankind itself. It is argued that technology has sparked an entirely new evolutionary phase for human kind. An analysis is performed that comes to the conclusion that use of technologies involves inconvenient questions and that risk, uncertainty and ignorance are very different things. Society itself must seek ways to address these questions and the desirability and possible implications of the answers to these questions because it is difficult for governments to establish the required regulatory oversight that would go beyond what is acceptable to the same society.

Introduction

What is the function of food for humans? The function of food can be defined as transferring energy and materials into organic components, which provide human beings with the energy and nutrients they need to function. But food is so much more. It is a carrier of our cultural values, traditions and even personal ideologies. The current food system is the product of a historic development pathway. It is not designed for flavour, nutrition or health. It was designed to produce calories, as cheap as possible. It does this really well until you factor in the impact – and costs - on the environment. For example, according to Olivier De Schutter, IPES-Food co-chair and former UN Special Rapporteur on the right to food, "it was calculated that a Big Mac should cost 200 euros when you calculate all costs involved".

Throughout history economic growth has been accomplished with negative environmental and humanitarian impact and the current food system is one of the largest contributors. Until very recently little has been done to avoid it. Some of the issues have been partially tackled but only a very few have been solved. The dilemma of the food system is a deeply existential one. On the one hand, we have a moral imperative to provide food for a growing population, on the other, doing so - based on the historic pathway - this will have devastating consequences for our environment. We don't want to provide temporary solutions at the expense of long term potential. As the food system has expended over the past decades, many of the concerns have come into sharper focus rather than becoming resolved.

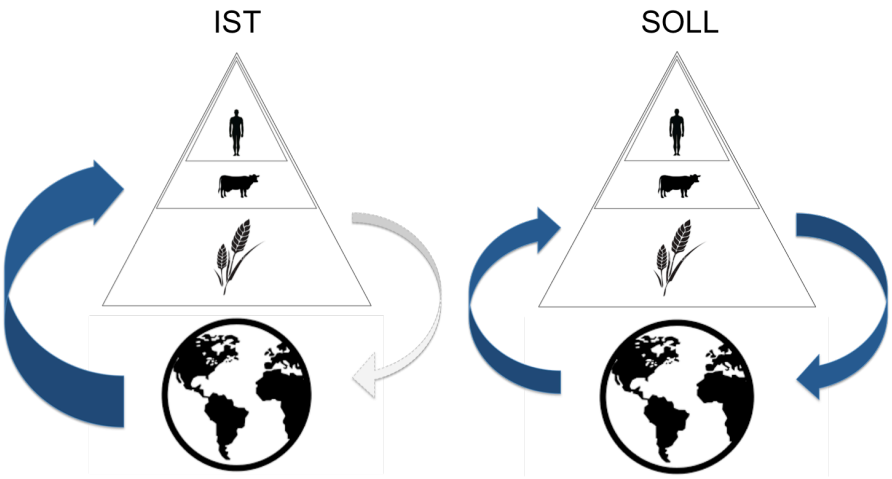
The result is that we are quickly approaching a planetary threshold; plenty of food is grown while still 70% of those who grow the food remain undernourished and another part of the population is obese. At the same time, a third of the total food production ends up in the garbage. We are increasingly aware of the fact that our behaviour affects not only our own future but the planet as a whole and all species who live on it. That's a big responsibility. And it seems we

are not equipped for this. Or are we? This calls for human stewardship. However, so far most attempts to drive such stewardship have failed.

Investments in innovation, both public and private, are driving forces behind economic growth and societal changes. Thus to make the changes need we need to focus on innovations that target –or at least include – the innovation of human stewardship. For this to be accomplished a much more accurate understanding of the effect of some of the newest technologies on human behaviour is required. The current state of the food system is the result of the behaviour of many different actors. We need a multitude of strategies at different levels to go beyond individual convictions in order to address the urgent challenges at hand. This essay focuses on the most present far reaching strategy; the innovation of humankind itself.

The Challenges in the Global food system

The challenges in the Global Food system are granular and complicated. There are no simple solutions. However, the common consensus is that technology will play a crucial role in addressing these challenges. Technology that is able to feed a growing population without the claim on the earth and future generations. Recent technological developments have been eye-catching. The speed at which technology is evolving is unprecedented in human history. Many understand that technology is changing the game, however there are very few that understand the full impact of today's technology on the world of tomorrow. While the global food system is faced with many challenges, the biggest challenge is the required transformation of human kind. We need to change human behaviour. We need to crack the evolutionary based bias of the human brain. According to Yuval Noah Harari (2012) research has shown that humans are not capable of thinking on behalf of more than 150-200 people therefore humans are not equipped to think on a large-scale planetary level. Nevertheless, we need to act on this level. And we need to act now! How? This remains to be seen but some technologies have the potential to solve many bottlenecks including taking away biological boundaries and push human kind forward. Technology can – both direct and indirect - help change consumer behaviour, and with it the entire food system. This is shown below.



There is a need to look beyond the individual parts of the value chain to gain a greater understanding of possible drivers and disruptive technologies. A challenge-based approach will bring together resources across different fields, technologies and disciplines. For example, in functional food Tech, Pharma and Food & Agri are combined. Thanks to recent research, ubiquitous mobile technology, cheap sensors and new food production methods, the idea of customized nutrition is making progress. Many companies are trying to develop a way to quickly and accurately measure a person's deficiencies in nutrients and then produce a tailored nutritional supplement.

People tend to look to technology to ease the pinch – after all, it has worked before. Between the 1940s and 1970s, major advances in technology – such as chemical fertilizers and pesticides, improved seed varieties, better irrigation and farm technology – led to huge gains in the amount of food the world's farmers were able to grow. Although some of these technologies were found to have drawbacks – for example, chemical fertilizer can deplete the soil of nutrients and pollute water – the 'green revolution' undeniably saved lives. Can technology do it again? Indeed, the speed at which technology is changing and evolving today is unprecedented in human history. Divergent technologies such as artificial intelligence, biotechnology and neuroscience, are not only accelerating but are converging and building on themselves, casing even faster rates of growth. Humanity has a unique opportunity to harness these technologies and use them to solve the challenges. However, for years the most important food innovations were all about scale. How could we feed a growing population at less expense? One option is by doing everything bigger because in a huge industry small steps matter. For example the average sugar content in one portion of Nesquik was 17.2 grams in 2000; in 2014 it was 10.6 grams, a 38 percent reduction. By changing just Nesquik, Nestlé has reduces its use of sugar worldwide by more than a million kilograms since 2014 (Kummer, 2015).

The promise of biotechnology

Fifty years hence, we shall escape the absurdity of growing a whole chicken in order to eat the breast or wing by growing these parts separately under a suitable medium.

- Winston Churchill, 1931

If we are really going to make a quantum leap, biotechnology is probably going to help. Biotechnology is a collective term for the deliberate (re)design and construction of new biological molecules, cell components and systems with the aim of removing elements and/or inserting non-natural elements into natural systems for specific purposes. It covers a wide range of applications and techniques. One of the techniques that catches the imagination of a wide public is CRISPR-Cas9, which is a revolutionary, but simple and inexpensive new technique for making highly targeted changes to genes in microorganisms, plants, animals and humans. It opens the door to new types of research, products and treatments. The rise and potential of CRISPR-Cas9 is closely associated with next generation sequencing, which provides the necessary sequence information and insights into which genes play which role. Germline applications would have implications not only for the individual plant, animal or human, but also for its genetic heirs (Pollack, 2015). If a CRISPR-Cas9 gene drive (a mutational chain reaction) is used, in theory it would only be necessary to release a limited number of genetically modified plants, animals or individuals in order to modify the entire world population. A CRISPR-Cas9 gene drive approach has already been demonstrated for fruit flies and mosquitoes under laboratory conditions (DeFrancesco, 2015).

Besides CRISPR-Cas9 there are several other technologies available with a potential huge impact. One of these is the use of RNAi technology. RNA interference (RNAi) is a process in the cell that regulates gene expression or destroys viruses. It can be used to block genes without

changing the cell's DNA. The first genetically modified insect-resistant crop based in RNAi technology is already on the market. The biggest potato company in the United States, J.R. Simplot, won clearance for a non-browning made using gene silencing. RNAi technology can also be used on conventional crops in the form of RNA spray to combat pests or influence plant characteristics. Another very interesting field of changing human behaviour is 'optogenetics'. Optogenetics involves genetic modifications by adding genes coding for light-sensitive proteins. Light can then be directed to specific neurons in the brain to either activate them which results in changes in behaviour.

Today genetically modified animals could produce more milk, meat or wool or produce less waste (manure). Various start-ups are working on the next step, cellular agriculture, in which milk, meat or wool is produced without the use of animals. New technological developments require new knowledge.

The impact of technology on Humans

Technologies like CRISPR-Cas9 and RNAi technology blur the distinction between products of genetic modification, products of classical mutagenesis and 'natural' products or organisms. This undermines the legal basis for the current EU legislation on genetically modified organisms (GMOs), which is based on this distinction. The use of RNAi in the form of spray is currently not covered by GMO legislation, but there is a possibility that residual genetic material (such as RNA) associated with genetic modification could remain on food or other products. Even if it presents no risk to humans, it could lead to public debate about the implications.

Technology can be applied to have a direct and/or indirect influence on the behaviour of humans. With regard to the indirect influence, in the past decade we have witnessed an immense growth in the possibilities that technology allows us to monitor people (geolocation, face recognition, emotional recognition). Big data driven artificial intelligence provides many option to monitor people and (subtly) steer their behaviour. Sensor technology is already taking personal space to an unprecedented degree. Think of wearable technology that keep track of food consumption patterns, nutrients intake, heart rate, cholesterol levels. What is the effect on human behaviour of such an environment? Several researchers (Schwartz, 1999 and Westin 1967) have stated that when individuals are aware of the fact that their actions are constantly being monitored, they find it much more difficult to do anything that deviates from accepted social behaviour.

Human behaviour is also indirectly influenced both by the genes that we inherit, the nutrients that we take via our food and the environment in which we live. With the significant advances in our knowledge of genetics there is more focus on the contribution of genes to behaviour. If genes that influence particular behaviour are identified, it could become possible to influence,

intentionally, human behaviour via food. Observational studies try to identify differences in genes that contribute to trait variations in characteristics or traits between individuals (molecular genetics). Currently the connection between genes and physical characteristics is far from straightforward and the relationship between genes and behaviour is even more complicated. Also, genetic influence on human characteristics is often misinterpreted. Behaviour is not biologically hardwired. Establishing that behaviour has an important genetic basis does not imply that this behaviour cannot be changed through environmental means. Therefore it is both our bodies and our behaviour have become objects of technological intervention. Recent technological developments illustrate this. Although genome sequencing has provided more and more information on the human genome, until recently it was difficult to act upon that information by intervening in a genome.

With CRISPR-Cas9 today we really do have the technological capability to change the genetic make-up of humans. But as we know nearly all new technologies have unpredictable effects on future generations. The history of this debate shows two different positions each of which are deeply entrenched in a cultural specific setting and beliefs. Some are in favour of exploring the potential of new technologies. Others are more sceptical. CRISPR-Cas9 has rekindled this debate. Countering the global threats will require action in several areas. In addition to better distribution of food and a reduction in post-harvest losses, improved quantity and quality of sustainable food production we need to change the consumption patterns. In order to solve the challenges in the global food system we have to become a better version of ourselves. Technology could do that.

Regulation; the difference between Risk, uncertainty and ignorance.

It is not for the first time that humanity struggles with regulatory challenges in the face of new technological developments. In order to apply the regulation that is fit for purpose a deep understanding of the technologies involved is required. In fact, the ability to understand technology and its implications has become increasingly problematic. As technologies move more and more into the background, designing meaningful transparency mechanisms might prove a big challenge. It is important to anticipate the ethical, legal and social implications raised by implementing such technologies. The individual may be afraid of technologies that operate and make decisions in the background, an environment in which individuals are steered to act in a way that he or she wouldn't have chosen otherwise. In many cases it is difficult to distinguish the outcome of new technologies from the outcome of traditional technologies. In the definition of genetic modified organism (GMO) a phrase has been included that states *'has been altered in a way that does not occur naturally by mating and/or natural recombinations' and 'cannot or are extremely unlikely to spontaneously arise in classical breeding or in nature'.* If CRISPR-Cas9 is used only to make mutations or deletions in genome, the end result would be the same as the outcome of conventional mutagenesis or 'natural' mutations and thus it undermines the legal basis for the current EU legislation on genetically modified organisms (GMOs), which is based on this distinction. Why is that important? It is because otherwise a directive would not be enforceable.

Our brain is biased toward 'new' means 'riskier'. But that is not always the case. The main difference between many of the conventional techniques and new technologies is that the latter is no longer a blind approach, but a knowledge based directed approach. For example conventional mutagenesis makes numerous random deletions and rearrangements in the genome. CRISPR-Cas9 only makes the specific mutations that are wanted, which makes the

technique safer. Gene editing is a much less blind approach than conventional cross-breeding. In terms of uncertainties or relative risks, there are also no reasons to place gene-edited crops that have alterations in their genomes that can also occur in nature, in a higher risk class than conventional cross-bred crops. On the contrary, from a scientific point of view, it would place these crops in a lower risk class. I cannot think of a defensible position that punishes plant breeders for knowing better what they do. It could be argued that the risk and reward can be balanced by a free choice and informed individual consent. This 'individually oriented' approach is used in a medical ethics regime. From a 'humanity as a collective' point of view this approach is inadequate because it does not take into account what is at stake for humanity and society as a whole. The latter, a collective approach is expressed in constitution like human right principles. The implications of a technology like CRISPR-Cas9 are both collective and individual. Given the speed at which these technologies have been embraced and the broad scope of its application and the far reaching implications and economic interests involved, action is required.

Regulation is often said to lag behind technological developments, but in the case of human germline engineering it is the other way around. It wasn't hard to renounce something that wasn't possible. Now things are different. Due to new technological breakthroughs a wave of legislation will be sparked which will result in a fragmented patchwork of policy instruments and government structures with limited enforceability. Giving the speed of developments, drawing up regulations and policy is not only undesirable, but almost impossible.

Conclusion

I have witnessed the industry from many sides of the table and I am convinced we need to focus on the weakest link in the global food system; the human component. This is not easy. Trying to shoe-horn a ‘what’s best for human kind’ mentality into an individual ‘what’s in it for me’ cannot portend a happy outcome. Our north star, guiding our actions, has always been the growth of the population. However, I am not convinced that a food demand problem, perceived as being primarily in markets with low buying power, is going to drive the big change needed – change human behaviour. Increase yield is a great way forward as long as you appreciate that it will be completely irrelevant for a large part of the issues presented in this essay and perhaps even worsens some of the issues in the long run. The Food & Agri industry should monetise its knowledge and leverage technology at a higher level. When taken today’s technological advancements into account it could not be clearer that we can do more, both in terms of raising awareness and driving innovation. We know what needs to be done, we know what could be done. The question is are we able to get on and do it? Our role is not to fix short-term issues while leaving the real problem – human kinds inherent vice – untouched. We must bring together people that share a common aspiration to do better, to be better and to make better.

Our brain reached its current state of evolutionary development some 200.000 years ago. In fact, over the last 20.000 years, the average male brain has dwindled by 10% in volume (equivalent to a tennis ball). Today technology triumphs humankind in many ways. Bartlet et al. (2014) show that current face reading technologies can already distinguish authentic from false expressions with an accuracy of more than 90 percent, while human average 55 percent, and technology has sparked an entirely new evolutionary phase for human kind, breaking free of a DNA-, gene- and carbon-compound-based evolution billions of years old. The ‘made’ (culture) and the ‘born’ (nature) are fusing. Traditional notions of nature have to be

reconsidered. ‘Natural’ exists only between our ears and is in fact a cultural construction. Technology impacts people who do not exist yet. Who has the right to decide which situations (food shortage, genetic disorders) are severe enough to justify the use of genetic modification? Who is willing to take that responsibility? And for what? Certain individuals? Or humanity? How do we channel public involvement in a meaningful and effective way? What are the correct value drivers of the desired socio-technological development? Which combination of measures will drive the change needed? How can we prevent ending up being the ones who serve technology? Are we truly serving the interest of human kind? Or are we just serving the needs of the industry or specific share/stakeholders?

If expensive technological treatments will only be accessible to a small group of people will technological enhancements aggravate the existing problems and differences between people? Is, even given the fact that there’s more genetic variation in the average chimpanzee troop than there is among the 7 billion people living on earth today, equal treatment under threat because not all are equal because an elite few use human enhancement to give their descendants an even greater competitive advantage?

It does not seem to be possible to give a simple yes or no answer to these questions. When the development of technology involves questions about its desirability and possible applications, we must seek to address any possible problems as early as possible to steer developments accordingly. It is not up to researchers to decide what research should or should not be allowed. We need a balanced consideration of both collective and individual values. Regulation may help to steer developments. However, history has shown us this most likely will not be sufficient. Indeed, Risk, uncertainty and ignorance are very different things. Political will and regulation will be crucial but by itself will not make the change needed. We need to shift from an isolated, siloed view to a more inclusive collaborative view.

There is no more exciting time to be on the front line of the technological revolution in general and more specific this revolution within Food & Agri. We need to get ready for a very techno-driven society that will have major consequences for how we view technology and ourselves. I call upon all actors worldwide to work hard to allow new technologies to develop responsibly.

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