What if CRISPR became a standard breeding technique?

New genetic technologies allow scientists to drastically accelerate the traditional breeding process, thereby achieving in years what previously took centuries. How will this change the way we produce food?

The breeding of plants and animals has been happening ever since the advent of agriculture. It involves selecting individual organisms with desired traits and making them reproduce with other organisms without losing the valuable trait, subsequently using the offspring as new stock from which to select new desirable traits. Over time, the bred organisms develop so many new characteristics that they are markedly different from their wild relatives. The conventional process takes a long time. Breeders have to wait for valuable traits (larger fruit, resistance to disease, more meat, etc.) to arise spontaneously, by extensive screening of crops using classical mutagenesis, or by crossbreeding to utilise the strengths of existing stocks of desired traits.

However, modern genetic techniques can speed up this process. Now, scientists can use the large amounts of genomic data available through DNA sequencing, as well as an increased understanding of molecular biology to determine the traits certain genes engender, and subsequently modify these genes by editing the DNA sequence. Whereas conventional breeders have to wait for the edit of the gene to occur spontaneously, breeders can now introduce the edit with precision. The most popular editing technology currently in use is CRISPR-Cas – a straightforward, efficient and cheap molecular tool that can be programmed to cut specific DNA sequences. It is in repairing these cuts that the sequence can be modified, using the cellular repair mechanisms of the organisms themselves. Scientists can use this method to knock out genes (make them lose their function), edit genes (modify a single pair or a few base pairs, i.e. letters of the DNA code), delete regions of DNA, or add DNA (foreign DNA, referred to as trans/cisgenes). At the moment, the most accessible edits are knock-outs of genes that have a clear correlation to a trait. However, more understanding of gene networks and systems biology, and further optimisation of the technology is likely to lead to more fundamental engineering, changing the biology of agricultural species to produce food with prescribed qualities.

Potential impacts and developments

In plants, research has focused on increasing yields, improving tolerance to biotic and abiotic stress, and biofortification. Biotic stress consists of viral, fungal and bacterial diseases. Abiotic stress can be environmental – relating to cold, salt, drought and nitrogen, or deriving from herbicide exposure. Biofortification increases the nutritional value of the plant. One example is the genetically modified organism (GMO) golden rice, which is enriched with beta-carotene, a precursor of vitamin A. The main species being edited in research are rice, maize, tomato, potato, barley and wheat. Examples include development of a variety of wheat resistant to powdery mildew (a type of fungal disease), enhancement of seed oil composition in camelina, and inhibition of fruit ripening in tomato. It is hoped that many of these CRISPR-Cas edited crops will be part of a transition to a more sustainable form of agriculture.
What if CRISPR became a standard breeding technique?

In animals, research has produced hornless dairy cattle, removing the need for painful dehorning, pigs resistant to classical swine fever virus, and beef cattle with larger muscles, for instance. The example of hornless dairy cattle is one of several initiatives aimed at reducing animal suffering in food production. Other research is geared towards producing beef cattle with male-only offspring and egg-laying hens that lay only female eggs. In both cases offspring of the other sex are now culled because they are not commercially useful.

These engineered plants and animals are only edited, in other words they contain no transgenes, i.e. genes from other species (even though this is possible using CRISPR-Cas). This means that all changes introduced could have occurred by random mutation or classical mutagenesis in conventional breeding. CRISPR-Cas does have the tendency to produce off-target effects, which means edits occasionally occur in other parts of the genome that were not targeted. This is not really a problem, as mutations also occur naturally in organisms, often without effect. Moreover, the edit itself and potential off-targets can be checked by DNA sequencing, allowing the selection of organisms with only the desired edits. Scientists are also working hard to improve the CRISPR-Cas system to reduce off-target effects and make it specific to the targeted sequence.

Policy can determine whether the technology contributes to more sustainable food production or, on the contrary, leads to an unfair distribution of the surplus value resulting from innovative gene editing.

Anticipatory policy-making

Given the rapid pace of scientific developments in the field of gene editing, its regulatory oversight seems more necessary than ever. In February 2017, the European Group on Ethics in Science and New Technologies (EGE) noted that the debate about genome editing should address not only safety, but also broader societal questions, such as justice, equality, proportionality and autonomy. In July 2018, the European Court of Justice (ECJ) ruled that genome-edited organisms qualify as products of genetic engineering and hence fall under the scope of the Deliberate Release Directive 2001/18/EC. According to the ruling, as genome-editing techniques have not yet demonstrated a long safety record in the open field or in a number of applications they cannot be exempted from the rules applying to GMOs.

The Commission is now working with EU Member States and stakeholders to implement the Court’s ruling. In October 2018, the Commission asked the European Union Reference Laboratory for GM Food and Feed (EU-RL GMFF), together with the European Network of GMO Laboratories (ENGL), to draw up a report on the detection of food and feed plant products obtained by new mutagenesis techniques. The report was published in March 2019. It highlights challenges and limitations relating to detection and identification, concluding that products of genome editing can only be readily detected in commodity products if prior knowledge of the altered genome sequence is available. During the 2014-2019 term, the European Parliament objected to every proposed authorisation of genetically modified food and feed, demanding the suspension of all GMO approvals.

In November 2019, the Council asked the European Commission to prepare a study on the status of new genomic techniques under EU law, by 30 April 2021, so as to minimise legal uncertainties in this area. The Commission is currently carrying out targeted consultations with Member States and EU-level stakeholders to gather information for this study. The main question that needs to be addressed is whether products developed using gene editing should be regulated on the basis of the process or the final product’s characteristics, or whether a hybrid approach should be taken.

As food safety is a sensitive matter of primary concern to all Union citizens, any policy initiative in this field should not only be informed by the findings of the Commission study and the respective public consultations, but also be grounded in the principles introduced by Regulation 2019/1381 on the transparency and sustainability of the EU risk assessment in the food chain and the need to accommodate conflicting value frames by broadening the scope of the risk assessment framework and/or by transforming ethical or socio-economic considerations into substantive regulatory standards.

This document makes use of material published in the March 2019 STOA paper on Farming without plant protection products. The authors are grateful to Prof. Barbara De Coninck, Division of Plant Biotechnics, KU Leuven, for reviewing the scientific elements.

The document is prepared for, and addressed to, the Members and staff of the European Parliament as background material to assist them in their parliamentary work. The content of the document is the sole responsibility of its author(s) and any opinions expressed herein should not be taken to represent an official position of the Parliament. Reproduction and translation for non-commercial purposes are authorised, provided the source is acknowledged and the European Parliament is given prior notice and sent a copy. © European Union, 2020.