New genomic techniques for improving root chicory – a European niche crop

Policy Brief on research and innovation achievements

Why targeting root chicory?

CHIC (Chicory as a multipurpose crop for dietary fibre and medicinal terpenes) was a large European Commission-funded Research and Innovation Project conducted between 2018 and 2022 to explore the potential of selected New Genomic Techniques (NGTs) for smaller crops in European agriculture by drawing on root chicory as a case study.

Root chicory – an underutilised low input, multi-purpose crop

Root chicory is an example of a crop that could potentially be used for multiple products, both in the food and non-food sector. Stakeholder engagement and social science tasks, as well as a broad range of communication and outreach measures including art & science activities, were conducted over the entire project period in order to provide guidance for responsible development to CHIC innovators.

EU companies are world market leaders in producing root chicory inulin

Root chicory is a niche crop which in Europe is mainly grown in Belgium, Northern France, and the Netherlands. In the Netherlands, for instance, it is cultivated on ca. 0.6% of the arable land. It is a domestic crop with a long history of cultivation and use in Europe. At present, the main product of root chicory is inulin, a dietary fibre used as food ingredient in many processed products. Inulin has confirmed and EFSA approved direct and indirect health benefits linked to gut health, e.g. probiotic effects, microbiome modulation, immune system support; it is a low calorie – sugar and fat replacer. The European companies located in this region are world market leaders in inulin production.

Chicory roots also contain other products of interest such as terpenes, but these are not yet utilised.

Root chicory is also a robust low-input crop and all side-products of inulin production can be used as feed or for bioenergy production. This makes it an interesting crop from a sustainability and circular economy perspective.

Root chicory is not very attractive for traditional breeders due to its niche character as well as the high breeding effort involved

Unfortunately, breeding of new plant varieties is very time consuming and typically takes about 12-15 years. In case of root chicory, breeding is particularly challenging partly due to its self-incompatibility, which does not allow self-fertilisation. These challenges result in high costs, which effectively hamper breeding programmes for minor crops with small market volumes. In case of root chicory, this not only precludes significant agronomical and quality improvements for inulin production but also the exploitation of terpenes from chicory roots.

Applying genome editing to a European niche crop

Against this backdrop, the achievements of the CHIC project are not only substantial for chicory innovation but also illustrate the potential of NGTs for niche crops and sustainable agricultural diversification in Europe. Within less than five years the project

Project Achievements

Speeding up the breeding process from 12-15 to 2 years

(i) successfully established the knowledge base for routine and safe use of four different New Genomic Techniques (NGTs) in root chicory, allowing shortening the breeding process from 12-15 to about 2 years.

(ii) obtained five new chicory varieties with direct and indirect health related properties for consumers and allowing for environmental improvements in the inulin production process: First, an inulin-improved variety, which shows no degradation of high quality inulin allowing longer harvesting time. Another variety has reduced amounts of the bitter compounds (terpenes) which allows skipping two steps in processing the roots. These two new characteristics were then combined in a third plant variety. The use of these varieties also reduces production costs as well as resource and energy needs. This would allow producing high quality inulin at a lower price and, therefore, inulin is expected to become an interesting compound to be used in a larger range of food products (partly replacing sugar). Thereby, producers, consumers and the environment can benefit.

Better quality inulin and longer harvesting periods

Two other chicory root varieties were developed accumulating two terpenoide compounds of interest. Terpenes have a broad range of proven positive health effects. The most well-known terpenoide is artemisinin used for WHO-recommended treatment of malaria. Artemisinin is produced as a pharmaceutical in large quantities from the plant *Artemisia annua* (sweet wormwood), grown in open field in many areas across the globe.

The project revealed that terpene extracts from chicory root have high antimicrobial, antifungal and anti-inflammatory potential, which could be explored further to be used in personal care products or as pharmaceuticals. Two root terpene extracts showed promising activities against antibiotic-resistant pathogens or as antifungal agents. These terpene extracts could even be produced from chicory roots in a combined process together with inulin from the same roots, which would also result in saving of resources, energy and time and, thereby, reduce the production costs and the environmental footprint.

Antimicrobial, antifungal and anti-inflammatory terpenes as a new root chicory product

The results of a Life Cycle Assessment indicate that using these varieties in commercial production of inulin would result in reductions of greenhouse gas emissions and of primary energy demand by up to 14% in comparison to the reference inulin production. Socio-Economic Assessment suggests a higher value added throughout the whole economy and the creation of more jobs. It also clearly shows that 80% of the value added remains in the EU – provided the new root chicory varieties would be cultivated in the EU.

Saving energy and reducing greenhouse gas emission

These promising new chicory varieties resulted from inactivation of selected genes by small genetic changes which – technically speaking – could also result from conventional breeding or natural mutations.

No DNA inserted, no off-target mutations detected

The different NGT methods used, i.e. variants of CRISPR-Cas implementation, were also investigated for off-target mutations. For none of the methods used and in none of the lines analysed off-target mutations were detected.

CHIC results illustrate the potential of NGTs for small crops, small markets, and SMEs in Europe

For the time being, the further exploration and use of these root chicory varieties by European SMEs for EU agriculture remains blocked as their present legal status as GMO comes with high costs for market authorisation and with a high business risk of developing products which will be stigmatised as GM food.

Competitor inulin producers in multiple other countries, including Chile and China, in contrast, could use these insights /these varieties to grow genome-edited chicory root plants as both jurisdictions do not subject such small genetic changes to a fully-fledged GMO risk assessment and labelling requirements.

The European Commission has recently conducted a public consultation on weather small genetic changes of this type should be subjected to a more risk proportionate legal regulation for cultivation and marketing. The CHIC project clearly shows the potential of NGTs for root chicory innovation. Beyond inulin and terpene production, a range of other traits could be targeted, e.g. susceptibility to certain pests. Until recently, these pests have been managed by a pesticide, now phased-out in the EU. Hence, chicory root production in the EU will also come under pressure from this side as more farmers are expected to pull out of chicory root production if no solution from crop improvement or crop protection is offered to them.

EU legal context encourages application by competitors – outside the EU and puts EU leadership at risk

CHIC was a Research and Innovation Action bringing together 17 partners from 12 countries for five years. The project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 760891. For more information: chicproject.eu.