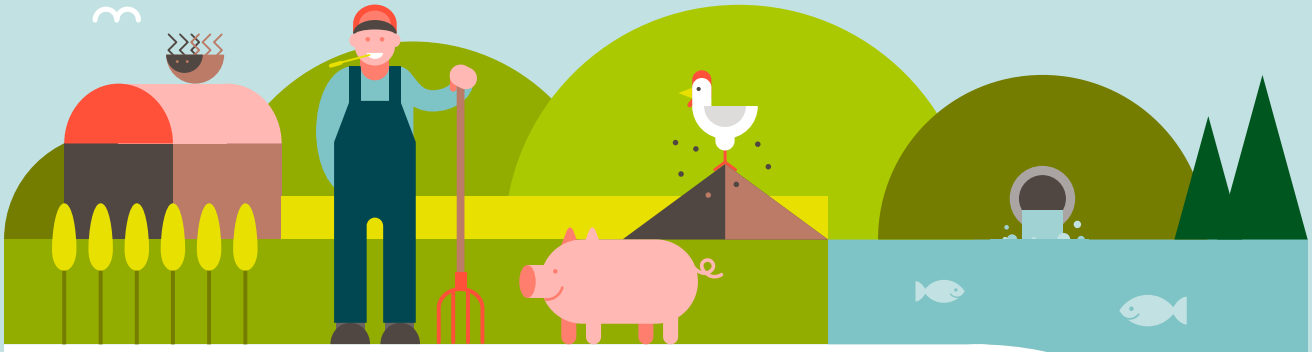
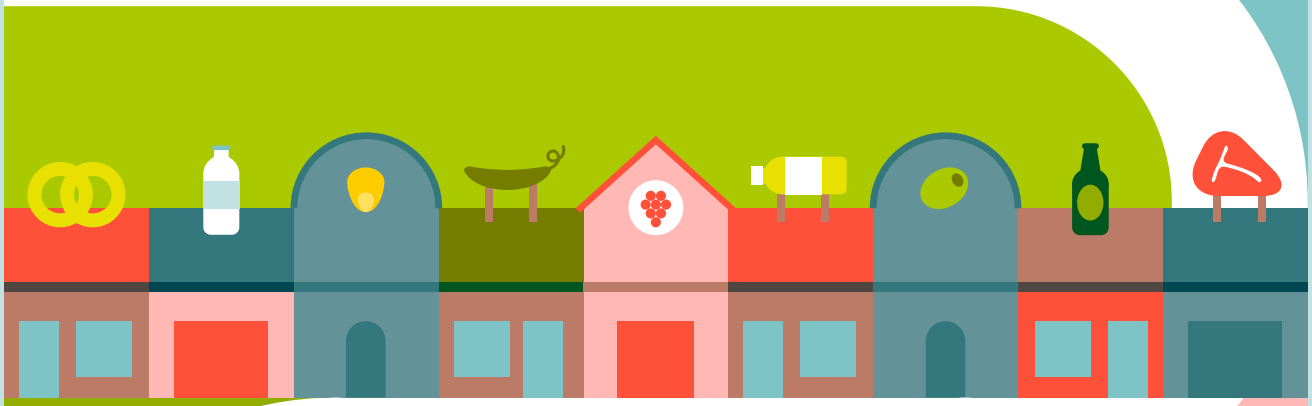
Whitepaper

The benefits of biosolutions to the European Union's Farm to Fork Strategy



Biosolutions from **FARM**...



...through **FOOD PRODUCTION**...

...to **FORK**

Rethink Tomorrow

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Contents

Message for policy makers

This document demonstrates that biosolutions have been contributing considerably to several items in the EU's Farm to Fork Strategy for long and that the potential of biosolutions to support the strategy further in the future is immense.

This applies to production in the agricultural sector as well as in the food production sector and covers both environmental benefits, population health benefits, and opportunities to maintain and improve the EU's competitiveness.

Biosolutions for agriculture

Approval times for new biosolutions for agriculture are long, and biological solutions for increasing yield and controlling pests in plant production are used only to a very limited extent in the EU compared with regions such as Latin America and North America.

The reasons for the long approval times are 1) that approval procedures are complex and, in some cases, follow the same guidelines as for chemical solutions, even though some of the biosolutions might be evaluated as low risk, 2) too limited regulatory resources at EU level with competencies to evaluate the dossiers, and 3) lack of priority.

The result is that while other countries like Brazil enable approval in 2-3 years of, for instance, biopesticides, it takes on average 6-7 years to approve the same product in the EU. This leaves no incentive for producers of biosolutions to seek approval in the EU as a first market.

With the current long approval times, the EU risks losing out on biological means to reach multiple targets in the Farm to Fork Strategy – including competition with other major regions in the world.

The EU is encouraged to shorten approval times for new biosolutions by taking two actions: 1) expanding EU level regulatory resources with competencies to evaluate the dossiers and 2) giving priority to approval of low-risk biosolutions with potential to support the Farm to Fork Strategy as described in this document.

Enzymatic biosolutions for use in the food industry

Regulation of biosolutions for the food industry, in contrast, is generally efficient in the EU and offers the technology to develop in line with demands in the market, to the continued benefit of the Farm to Fork Strategy.

Innovative protein sources

Regulation of protein produced in fermentation systems for human consumption falls in the EU under the Novel Food procedures which are complex, data demanding and with long regulatory timelines. The regulatory process is challenging for applicants and can easily take three years from submission of an application to approval. The similar timelines in the United States are normally less than a year.

Innovative protein sources are not in scope of this document as they are still new. Preliminary studies (not published) show, however, that they could benefit the same items in the EUs Farm to Fork Strategy as the plant-based proteins. See page 18.

It could benefit the EU's position in this upcoming market if rules and procedures for Novel Food approvals were modernized and approval timelines were shortened. For instance, by modernizing guidance documents to applicants and making data requirement proportionate to the risk profiles of the products.

Executive summary

The European Union (the EU) established a comprehensive strategy in 2020 called the “Farm to Fork Strategy” under the Union’s “Green Deal”. The aim was to ensure that the European population gets healthy, affordable, and sustainable food while ensuring competitiveness of food production in the region.

It is well known that many food and beverage products such as bread, cheese, wine, and beer are produced with the help of microorganisms. It is less well known that the potential of biological processes is greater than this. Biological tools such as specialized enzymes and microorganisms (commonly known as biosolutions) are widely used in agriculture and food industry because they

- increase yield in food production
- reduce energy, water, and chemical consumption in food production
- make possible new types of food and beverage products

and thereby contribute to the industries’ competitiveness.

The aim of this document is to show how the use of biosolutions not only benefits the users of biosolutions in agriculture and food industry but also benefits consumers and the surrounding society.

The document describes how microorganisms found in nature are turned into biosolutions and the benefits they offer to the European Union when used in different processes in the food value chain.

The summary table below shows the societal benefits of biosolutions in the context of the EU’s Farm to Fork Strategy. It shows that there are plenty of matches between the societal benefits that biosolutions can offer and specific items in the Farm to Fork Strategy.

For instance,

1. Biosolutions can help reduce **energy** consumption and impact on the **climate** and **biodiversity** because they increase yield in plant and livestock production as well as in food processing.

2. Biosolutions can support development towards **sustainable diets** and **resilient food systems** by supporting plant-based proteins for human consumption and by making plants less vulnerable to droughts.

3. Biosolutions can remove unwanted substances from milk, margarine, processed meat products, and baked goods and support **healthier diets**.

4. Biosolutions can help reduce **pesticide** use in plant production by offering biological alternatives to chemical treatments.

5. Probiotic biosolutions can improve production animals’ health and reduce the need for **antibiotics** in livestock production. Biosolutions can also make plant-based protein products more attractive. Plant-based protein can be produced without any use of **antibiotics**.

6. Biosolutions are simple to use and can benefit **competitiveness** of companies of all sizes, including small and medium-sized enterprises, **SMEs**, a) by reducing spendings on energy and raw materials, b) by streamlining production processes and c) by serving as tools in development of new and improved food and beverage products.

The use of biosolutions is driven by the market and there is a wide variety of biosolutions in use in food production in the EU today. Innovation is comprehensive and there is a constant flow of new biosolutions designed to meet evolving needs in the industry.

Summary of items in the EU's Farm to Fork Strategy where biosolutions currently contribute

Item in the Farm to Fork Strategy	Effect of biosolutions	Societal benefit of biosolutions
Reduce consumption of **energy**	Enable energy savings in agriculture and several food industries	Reduce pressure on energy supply systems
Reduce impact on the **climate**	Enable yield improvements and energy savings in agriculture and many food industries	Reduces greenhouse gas emissions directly from food production processes as well as indirectly via reduced energy needs
Reverse loss of **biodiversity**	Enable higher yields and reduced emissions from agriculture, livestock production and the food industry	Yield improvements which reduce the amount of land needed to produce food. Less land needed for food production eases the pressure on biodiversity on land
		Improved yield and fewer emissions to lakes and rivers and coastal zones reduce pressure on biodiversity in water
Reduce **antimicrobials** for farmed animals by 50% in 2030	Better livestock health	Reduce the need for antimicrobial treatment of sick animals
	Enable more plant-based protein for human consumption	Plant protein can be produced without the use of antimicrobials
Reduce **pesticides** by 50% in 2030	Enable biological pest management in plant production	Conventional pesticides can be reduced without compromising productivity
Sustainable **livestock** farming	Enable that livestock farmers save feed for their animals without compromising animal growth	Livestock feed saving reduces pressure on climate and biodiversity because less land is needed to produce feed and emissions from manure are reduced
Strengthen **resilience** of food system	Make plants in agriculture less vulnerable to drought etc.	Help stabilizing output from agriculture
	Improve taste, texture, and digestibility of plant-based protein products	Enable diversification of protein supply towards plant-based proteins

Item in the Farm to Fork Strategy	Effect of biosolutions	Societal benefit of biosolutions
25% **organic farming** in 2030	Improve taste and texture of plant-based protein products	Plant-based protein can save agricultural land compared with animal-based protein and be an enabling factor for the desired increase of organic farming, which requires more land than conventional farming
	Enable biological pest management in plant production	Less dependency on chemical-based pest management is an enabling factor for extended organic farming practice
Healthier diets	Remove lactose from milk	Allow lactose intolerant individuals to include milk products in their diet
	Reduce acrylamide naturally occurring in baked goods	Reduce people's intake of acrylamide with baked food products – acrylamide is a suspected carcinogen
	Produce a savory broth from meat remaining on bones in the meat and fish industry for use in sausages and pâtés etc.	The broth can reduce the need for salt as taste enhancer and help reducing excessive salt intake in the population
Reduce **food waste**	Enable bread to stay fresh and soft for longer	Motivate consumers to throw less bread away because staling is delayed
	Support utilization of meat on bones in the fish and meat processing industries	Reduce how much meat is wasted or used for animal feed and increase how much meat is used for human consumption
Competitive and sustainable through "new opportunities"	Enable producers of food and beverage products to 1) save raw materials and energy 2) diversify raw material sourcing and 3) make new products and product variants.	Reduce food and beverage industry's raw material spendings and open new market opportunities

Biosolutions' contributions to the EU's Farm to Fork Strategy are specified in further detail in Appendix 1.

Infographic

The benefits of biosolutions to the EUs Farm to Fork strategy

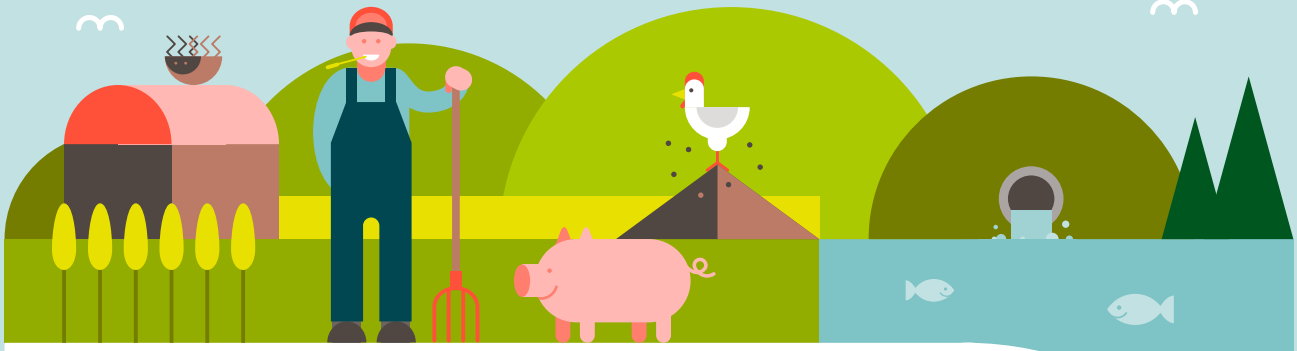
Better resistance to drought in agriculture is good for food security

Biological pest management in plant production can save chemical pesticides

Better yield in agriculture benefits biodiversity on land

Better utilization of feed for livestock lessens greenhouse gasses from manure

Less run-off to lakes and rivers is good for biodiversity in water



Biosolutions from **FARM**...

Improved yield of raw materials saves agricultural land for improved biodiversity

By saving energy we will have less impact on the climate

Making processes run smoother improves competitiveness

Enabling new products improves food security and health

Better utilization of side streams reduces waste

...through **FOOD PRODUCTION**...

Lactose free dairy products

Wine with a better color, flavor and mouthfeel

Broader variety of beer with better taste

Plant-based dairy and meat products with better taste and texture

Cheese with better flavor and texture

Juice with better clarity, color and smoothness

Bread that is healthier and stays fresh for longer

Patê and sausages with less salt

...to **FORK**

Better and new products for the population and competitiveness of the food industry.

Many of the food products that consumers take for granted today would be more expensive, poorer quality or hardly exist if it were not for the use of enzymatic biosolutions in the food industry.

Introduction

The European Union established a comprehensive strategy in 2020 called the “Farm to Fork Strategy” under the Union’s “Green Deal”. The aim was to ensure that Europeans get healthy, affordable, and sustainable food while improving economic return in the food chain and ensuring competitiveness of food production in the EU.

One of the environmental means to reach these targets is to reduce greenhouse gas emissions and waste in the food chain. Others are to reduce the use of pesticides and the loss of nutrients in agriculture and to reduce the pressure on biodiversity.

It is well known that all the food that we eat has a biological origin in plant or animal production and that no food would exist without biological processes. It is also well known that many daily life food products such as wine, beer, cheese, bread, yogurt, and soy sauce are based on biological processes where yeast or bacteria play a pivotal role.

What is less known is that the potential of biological processes is greater than this. Microbial tools such as enzymes and specialized microorganisms (hereafter called biosolutions) can be used to

- increase yield
- reduce energy, water, and chemical consumption
- make new types of products possible

in all steps of food production from farm to fork.

Biotechnology is based on decades of research in microorganisms, and development and production of microorganisms and enzymes requires high levels of academic skills. The final products, however, are easy and safe to use, and companies of all sizes and education levels can benefit from the opportunities they offer.

The use of biosolutions in industry is market-driven and has existed for decades in the EU and other parts of the world. The technology is attractive because of the competitive edge that the products make available to the user – whether it is production efficiency improvements or higher value of the final product.

The use of enzymes in industry has been subject to numerous environmental assessment studies. These have consistently shown environmental benefits (link). The reason is that enzymes act catalytically and make processes happen at lower temperatures, with fewer chemicals added and with lower raw material and water consumption.

Copenhagen Economics has assessed the global achievable greenhouse gas emission reduction potential of mature, ready-to-deploy biosolutions to be around **4,300 million tons of CO_2 equivalents in 2030**, corresponding to around eight per cent of current emissions globally (link).

The aim of the present document is to unfold what biosolutions can offer to the EU’s Farm to Fork Strategy today and how they can add even more to the Strategy in the future.

What are biosolutions?

The core of biosolutions are microorganisms and enzymes.

Microorganisms

Microorganisms are living cells which can only be seen in a microscope.

They live everywhere on earth, in multiple forms in water and soil as well as in our bodies.

Some of the most common types of microorganisms are bacteria and fungi.

Bacteria can be used to produce, for instance, yogurt. Fungi can be used, for instance, to produce vinegar.

Bacteria and fungi can also be used to produce enzymes.

The acidic taste that we know from yogurt is produced by a bacterium called lactobacillus. It converts natural sugar in milk (lactose) into milk acid.

Enzymes

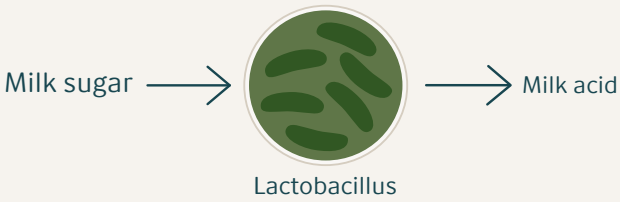
Enzymes are proteins with an active site. They speed up biological processes and are essential to any type of life.

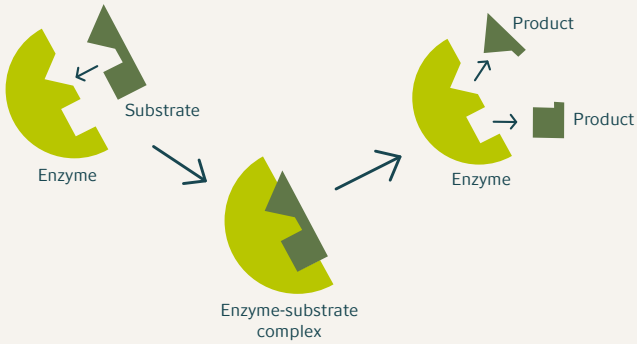
Enzymes have been used by humans in production processes since ancient times.

Today, enzymes are produced by microorganisms in fermentation tanks.

The fermentation process is also known from brewing. The main raw material is sugar, used as feed for the enzyme-producing microorganisms.

When a substrate, such as lactose in milk, reaches the active site of a specific enzyme, it is broken into pieces. This enables, for instance, dairies to produce lactose-free milk products.





When micro-organisms and enzymes are used to produce something valuable to humans, they are called biosolutions

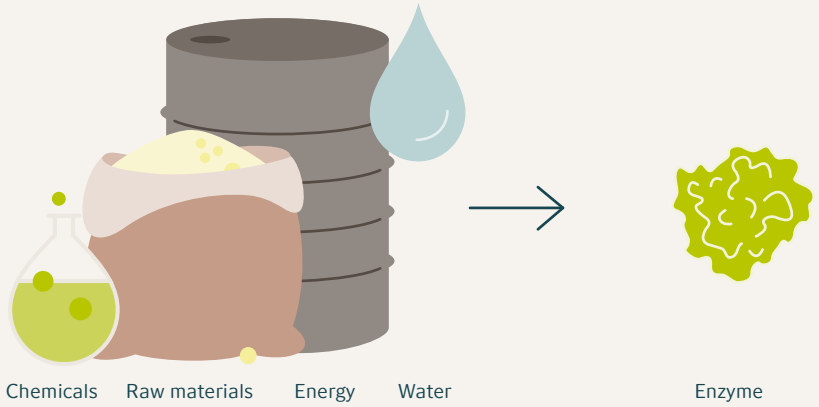
Microorganisms are found in nature

Microorganisms are found in various places in nature. Here, for instance, a fungus on a dead branch.

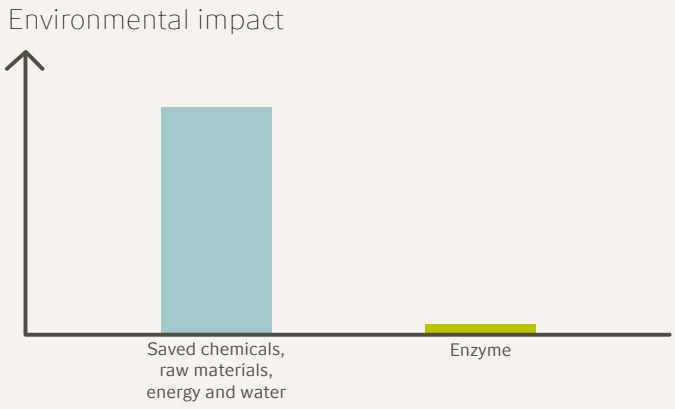
Microorganisms are isolated in the laboratory and optimized for safe and efficient use, for instance, using gene modification.
See Appendix 2.

Enzymes and microorganisms are produced by fermentation in closed steel tanks.

Environmental benefits of using enzymes



Substantial amounts of chemicals, energy, raw materials, and water can in many cases be replaced by a small amount of enzyme



The environmental impact of producing the enzyme is typically low compared with the impact of the savings. Link

Microorganisms for higher and more stable yields in agriculture

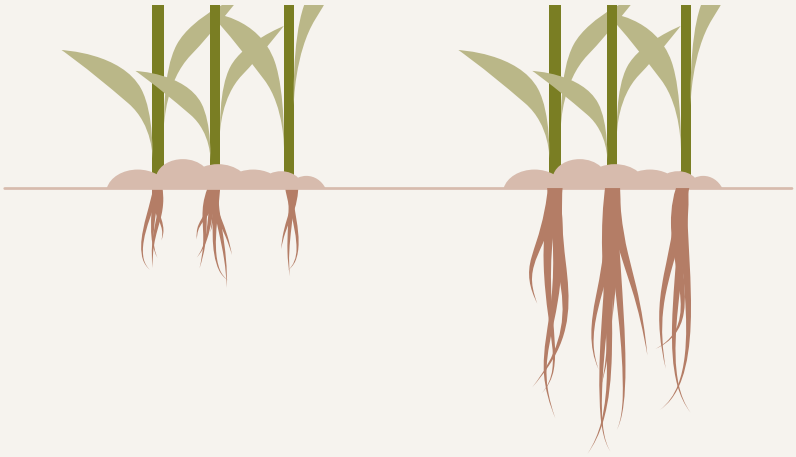
Microorganisms can be combined with crop seeds such as corn, soybean, oil seeds and wheat. After sowing, the microorganisms grow with the plant roots, supporting their growth and enhancing nutrient availability for the plant. This supports the growth of roots and shoots and increases crop yields.

This contributes to the EU's Farm to Fork Strategy on

Food security
Increase in root formation makes the plant more resilient to droughts because it can get better access to water and nutrients, also in periods with little rain. This adds to food security because plants have a better survival rate, better utilize the soil available and added fertilizers, and provide more stable outputs of crops.

Biodiversity on land
The increase in yield of crops has a positive impact on biodiversity and other environmental factors, because a smaller amount of soil is needed to produce the same amount of crops.

Climate
The better crop yields and increased resilience to drought is beneficial for the climate, because more can be produced with the same amount of fertilizer and field work such as ploughing and harvesting.



Without microorganism

With microorganism

Crop's root formation can be stimulated by the addition of microorganisms to the seeds before sowing, and this has a beneficial effect on the yield.

The yield of corn, for example, can be increased by 330 kg per hectare using a specific microorganism.

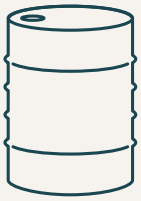
EU

Yield enhancing microorganisms are only used to a limited extent in agriculture in the EU today. One reason is that it is complicated for operators to bring new products to the market because Member States have different approaches to the regulation. Microorganisms are already widely used in many other regions such Latin America and North America, where they provide significant yield benefits, allowing many farmers in the Americas to be more competitive. More harmonized approval procedures across Member States could benefit the wider use of yield enhancing solutions in the EU.

Microorganisms for pest management in plant production

Microorganisms such as bacteria and fungi can be used to control pests in plant production. This can help maintain yields in agriculture field crops, as well as in fruit and vegetable production, and is a critical tool in reducing chemical pesticides.

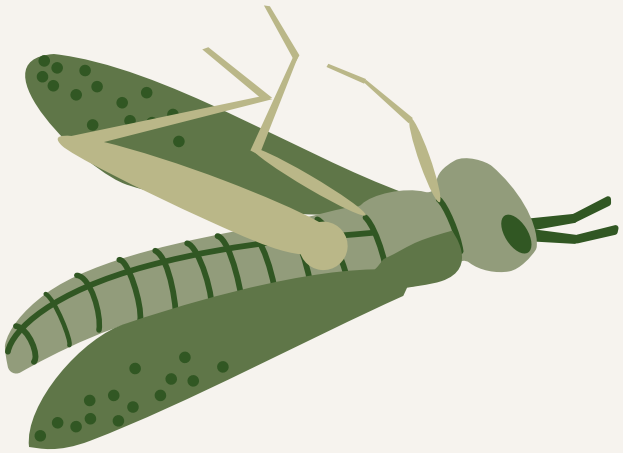
This contributes to the EU's Farm to Fork Strategy on



Pesticide
Fewer chemical pesticides used in plant production reduces the amount of toxic chemicals that are spread in the environment without compromising yields.

Resistance
Pests and pathogens can become resistant to chemical pesticides over time. Microbial pest management is a highly effective tool to manage and limit resistance development.

Competitiveness
Microorganisms are used in small quantities and give farmers greater flexibility at harvest. This is because no chemical residues are left on the plants and the required time between the last application and the harvest is shortened. This makes it easier for the producer to harvest at the optimal time and still be compliant with food chain requirements.



FAO promotes the use of biopesticides in the battle against grasshopper swarms as it has "very little, if in any, negative impact on human health and the environment". Link

EU

Biocontrol products for pest management are only used to a very limited extent in the EU today, as approval for these products has to follow the same stringent guidelines as for chemistry and because of a lack of regulatory resources at EU to evaluate the dossiers. The process is faster in other regions of the world and as a result, there is no incentive to seek approval for these novel solutions in the EU as a first market. Today, there is an increasing number of biobased pest management products approved commercially outside EU, and the pace of innovation is rapidly increasing.

Enzymes for better feed uptake in animal production

Production animals are not able to fully digest the feed they eat, and valuable nutrients pass through their bodies unutilized. This is inefficient for the animal producer and a concern for the environment because feed consumption is higher than necessary and because the unutilized feed substances end up in the surroundings with the animals' manure.

Enzymes can help animals get more nutrients out of the feed they eat and thereby save on supplied feed and agricultural products. The addition of feed enzymes reduces the overall agricultural land-use, greenhouse gas emissions from animals' metabolism (such as methane), and problematic compounds in the manure, such as nitrate and phosphate, thereby reducing environmental impact caused by manure management.

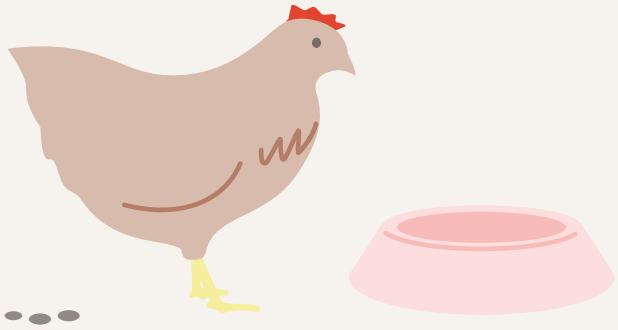
Efficient utilization of feed for production animals contributes to the EU's Farm to Fork Strategy on

Climate
Use of feed enzymes benefit the climate because greenhouse gas emissions from feed production and manure management are reduced.

Biodiversity in water
Improved nutrient uptake in the animal's digestive system reduces the amount of nutrients in manure. This benefits life in water in the local environment as less nutrients from stables etc. will run off into lakes and rivers and make algae grow out of control.

Biodiversity on land
Feed saving is beneficial for biodiversity on land because less land is needed to produce crops for animal feed.

Reduction of antibiotics
Biosolutions can improve animal health and reduce the amount of antibiotics used in animal farming.



Use of enzymes in pig and poultry production increases feed uptake. This saves feed and reduces emissions with manure. A single enzyme for poultry can, for instance, improve feed conversion rate by 3%

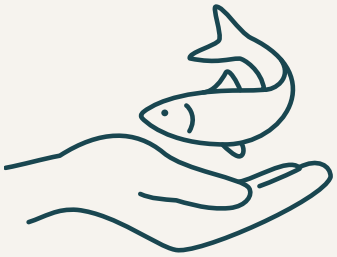
EU

Biosolutions are widely used in dairy, pig, and poultry production in the EU and globally and provide important benefits in animal nutrition while reducing the amount of animal waste. New and more efficient biosolutions are in development and provide a near-term opportunity to further improve animal health and nutrition as well as potential to reduce the use of antibiotics and other growth promoters.

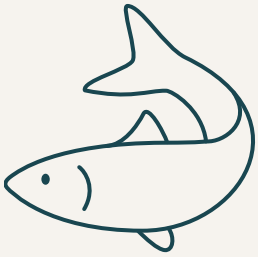
Microorganisms for better yield in aquaculture

Aquaculture is the practice of farming fish and shellfish in ponds. With many fish or shellfish in a pond, it can be a challenge to keep the water clean with adverse effects on growth and survival rate. Microorganisms and enzymes can be used to keep pond water fresh and animals healthy and thereby contribute to high survival rates and high yields. In shrimp farming, a microorganism can help delivering 33% higher yields

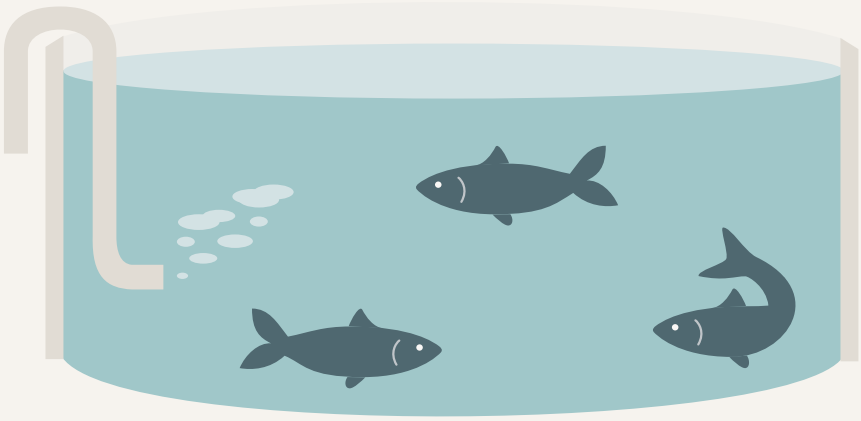
This contributes to the EU's Farm to Fork Strategy on



Food security
Fish is a healthy source of food for humans. Use of enzymes and microorganisms in aquaculture supports food security 1) by helping to ensure high and stable yields in production and 2) by supporting aquaculture business as a supplement to captured fish.



Biodiversity in water
Harvest from capture fisheries has not increased since the mid-1980s and output from aquaculture is now at the level of the output from capture fisheries. Continued growth of aquaculture is necessary to protect wild fish stocks and sustainably feed a growing world population. Use of biosolutions supports productivity in aquaculture thereby reducing the pressure biodiversity in water.



Global output of fish from aquaculture has grown steadily in the past decades and now exceeds output from capture fisheries.

EU

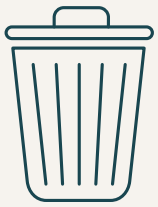
Biosolutions for aquaculture are currently of limited use in the EU compared to other regions such as South America and Asia. High regulatory standards are required to introduce new biosolutions through the feed, but the low production volume of aquatic species in the EU makes it cost-prohibitive when compared to evaluations in poultry or swine. Biosolutions could greatly improve water quality, which directly impacts fish health and performance as well as improve quality of discharge waters, if it were implemented more in the EU.

Enzymes for health and freshness of baked goods

Enzymes can be used to modify flour and dough prior to and during bread making. This can enable bakeries to use local grains for bread making and help bakers save baking energy and avoid chemical ingredients. Furthermore, it can help improve the quality, affordability, and health of baked goods. One significant quality improvement is reduction of acrylamide in bread; another is keeping bread soft for longer.

These two biosolutions contribute to the EU's Farm to Fork Strategy on

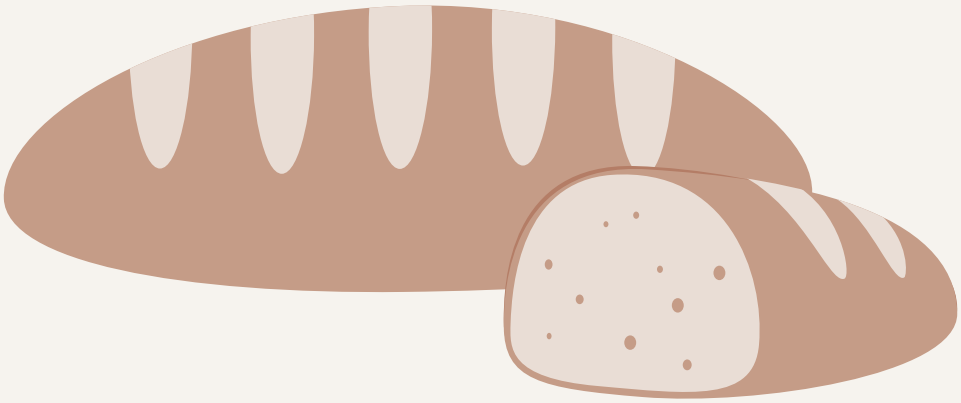
Human health
Acrylamide is a suspected carcinogen that is naturally formed during any baking process. The use of enzymes can reduce acrylamide content in products such as biscuits, crackers, and toasted bread by up to 95%.



Food waste
Stale bread is unpleasant to eat and tends to be thrown away. An enzyme can be used to keep bread soft and enjoyable for longer. Keeping bread fresh for longer motivates retailers as well as consumers to throw away less bread.

Climate
Reducing bread waste is a benefit for the climate because energy, flour, and water as well as packaging and transport is saved in all steps in the bread supply chain.

Biodiversity on land
Bread production uses grains as the largest ingredient. Reducing bread waste and upgrading lower quality flour for use in baked goods also reduces the amount of land that is needed for agriculture with benefits biodiversity on land.



Keeping bread soft and enjoyable for long motivates retailers as well as consumers to throw away less bread.

EU

Enzymes have been widely used in the baking industry since the 1990s in the EU and elsewhere, and consumers have for long taken benefit of, for instance, bread that remains soft and moist for long. Today there is a constantly developing portfolio of enzymes available for bakers to improve their bread, handling variations in flour quality, enabling local grains, reducing chemicals on the ingredient list and finally to enable more fibers and protein in the bread.

Enzymes for milk and cheese

Milk

Lactose is a sugar that occurs naturally in milk. Some people are intolerant to lactose and cannot tolerate milk. Lactose intolerance is highest in Asia where 65% of population is affected and lowest in Northern Europe where approximately five percent of the population is affected. The use of enzymes enables dairies to produce lactose-free milk.

This contributes to the EU's Farm to Fork Strategy on

Removing lactose from milk offers people with lactose intolerance an option to include milk in their diet. Milk is an important element in many people's daily food intake.

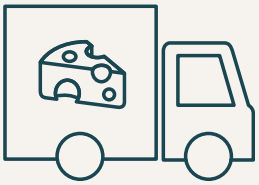
Cheese

Use of an enzyme in, for instance, mozzarella production increases the yield of cheese by up to 3.8% and saves milk. This is a benefit for the dairy, which can get more value out of the raw milk, and to the environment, because less milk is needed per unit of cheese produced.

This contributes to the EU's Farm to Fork Strategy on

Climate
Saving milk in cheese production reduces the pressure on the climate because less greenhouse gases are emitted from dairy cows.

Biodiversity on land
Less use of milk in cheese production benefits biodiversity on land because less land is needed to produce feed for dairy cows.



Competition
Enzymes are also used to develop specific cheese flavors and give cheese makers a competitive edge in the market.

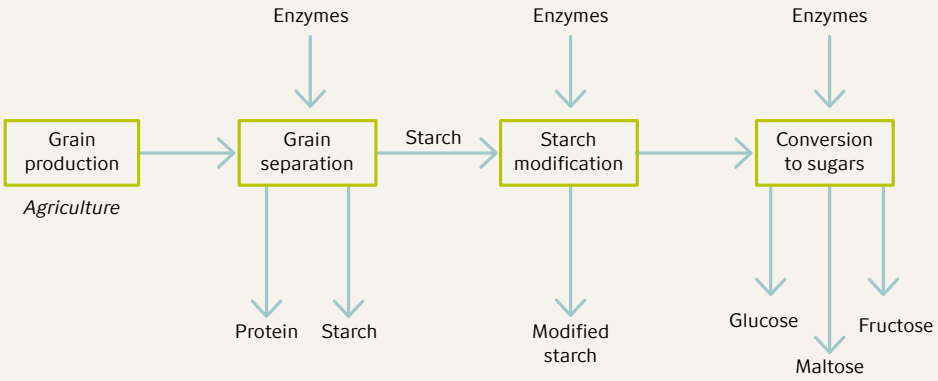
EU

Enzymes have been used to produce lactose-free milk for decades in the EU. In the past decade, a range of novel enzymes have been designed for yield increase in cheese making, to the benefit of the cheese manufacturers' raw material expenses and the sector's carbon footprint.

Enzymes for starch, protein, and sweetener production

The starch industry is a complex industry where grains such as corn and wheat are converted into starch, sweetener, and protein products. These are used in a broad range of food and beverage products such as bakery and biscuit products, soups, processed meat products, ice creams, desserts, jams, soft drinks, canned fruits, and dairy products.

Enzymes are used in all processes in the starch industry. In grain separation, enzymes open the fiber structure of the grain for better starch and protein extraction and for a better separation of protein and starch. In the starch modification process, enzymes are used to liquify the starch and convert it into a variety of sugars – glucose, maltose, and fructose.



Enzymes are essential in the starch industry where grains are converted into starch, protein, and sugar products, which are used in many food products.

Maltodextrins and fructose can only be commercially produced with enzymes today, and glucose production has now also been entirely converted to a biobased process, saving energy, and driving a more sustainable supply chain with less energy and chemical consumption.

Use of enzymes in the starch industry contributes to the EU's Farm to For Strategy on

Climate
The use of enzymes in corn and grain separation saves energy and increases yield of starch. The use of a single enzyme in corn milling enables 4.5 kg more starch to be extracted for every ton of corn processed, and that impact on climate is reduced by 1%.

Competition
Enzymes enable the starch industry to deliver advanced high-quality starch, sweetener, and protein products at high yields. This helps to keep competitive the starch industry itself as well as the entire food industry.

EU

Enzymes have been used for decades in the starch industry in the EU and are the main tool employed today for processing grains into starch and protein. As enzyme technology continues to evolve in this space, it offers producers an opportunity to drive better productivity while offering energy and water savings. Many of the industry-made food products that consumers take for granted today would be more expensive, of poorer quality or would hardly exist if it were not for the use of enzymes in the starch industry.

Enzymes as enablers of plant-based protein products

Consumers nowadays embrace plant-based dairy and meat alternatives, as awareness of the health and environmental aspects of food consumption increases and the alternative products' taste, texture and appearance improve. Enzymes are important enablers in this process because they can:

- Enable to achieve a desired viscosity and sweetness of plant-based milks
- Eliminate bitterness and off-flavors that come naturally with some plant proteins
- Improve digestibility of plant proteins
- Enhance taste and texture of plant proteins
  (for instance, umami taste for plant-based meat products and avoid lumps in protein rich plant-based yogurts)
- Ease the processing and enable better use of raw materials
- Replace additives and reduce number of substances at ingredient list on consumer products

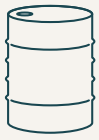
Plant-based protein is less resource-intensive to produce than animal-based protein, and it causes less emissions than animal-based protein production.

The use of enzymes to increase consumers acceptance of plant-based proteins as supplement to animal-based proteins supports several elements of the EU's Farm to Fork Strategy:

Climate
Reduces pressure on the climate – because greenhouse gas emission of plant-based products is small*.

Biodiversity on land
Reduces pressure on biodiversity on land – because use of agricultural land for plant-based products is small*.

Biodiversity in water
Reduces pressure on biodiversity – because there are no emissions to lakes and rivers etc. from any manure*.



Fertilizer and pesticides
Reduces fertilizer and pesticide consumption – because grain consumption for plant-based products is small* and less grain-fields need to be fertilized and protected against pests.

Antimicrobial resistance
Reduces risk of anti-microbial resistance* because no animals need treatment against diseases during production.

Food security
Increases food security because protein supply to the population can be diversified.

Organic farming
Production of plant-based proteins uses a small amount of agricultural land* and can support EU's ambition to foster organic farming because it releases agricultural land for less intensive plant production.

Competitiveness
The market for plant-based protein is competitive. Use of enzymes in production can enable new and better products and put manufacturers in a favorable position.

* In comparison with animal-based protein products

EU

Enzymes have been used for plant-based protein products for more than a decade in the EU. The exploration and discovery of new biosolutions in this field is accelerating these years and is essential as this will give answers to 1) a growing and urgent need of more and alternative protein and 2) the demand for a broader variety of plant-based consumer products and plant-based ingredients.

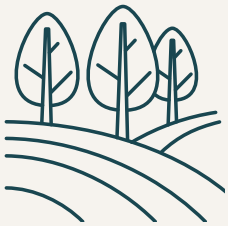
Enzymes for better yield and better juice and wine products

It can be difficult to squeeze the last drops of juice out of fruits in juice and wine production. Enzymes can help break down the fruit cell walls during mashing and increase the yield of the process by up to 20%.

Enzymes can also be used to facilitate processing in the two industries and to make better quality juice and wine products.

In wine making enzymes can, for instance, enable faster clarification and maturation processes. This improves the color, flavor, and mouthfeel of the wine. In juice production enzymes can be used, for instance, to improve the clarity, stability, color, and smoothness of the final product.

This contributes to the EU's Farm to Fork Strategy on



Biodiversity on land
Increased yield of juice extraction enable more juice and wine production with the same amount of fruit. This is good for biodiversity on land because less land is needed to produce fruit for juice and wine.

Competition
Smoother production processes with better yields save costs on the production side. Better quality products open new opportunities in the market. Both contribute to juice and wine makers' competitiveness.

Use of enzymes in the fruit extraction process increases the amount of juice or wine that can be produced from a certain amount of fruit.

EU

Enzymes have been used in wine and juice making in the EU for decades. Juice producers have used enzymes since the 1950s and winemakers since the 1970s with considerable value added both on the productivity side and the quality side.

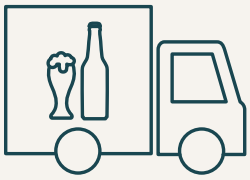
Enzymes for optimizing and diversifying beer production

Brewing is a biological process in which starch-based raw materials (such as grains) are converted into beer using malt-derived enzymes. Adding industry-derived enzymes can support and facilitate the process, helping to save energy, water, and raw materials in beer production as well as creating new styles of beer.

This contributes to the EU's Farm to Fork Strategy on

Climate
Reducing the energy consumption in the brewing process translates to direct savings in electricity and steam consumption. On top of this, reducing the amount of grains needed in the brewery, due to higher yields, reduces greenhouse gasses from agriculture. A single enzyme solution has been demonstrated to be able to reduce the climate impact of a beer by 8%.

Biodiversity on land
Grain savings achieved by yield improvements also benefit biodiversity, as less cultivated fields and less freshwater are required to produce the same amount of beer.



Competition
Enzymes can be seen as biological tools in the brewers' toolbox, which offer a pallet of opportunities in a competitive market. For instance, certain styles and categories of beer, with unique appearances and tastes, would not have been possible without the usage of enzymes.

Consumers demand a broad variety of beer styles today: Specialty beers with unique flavors, low-calorie beer, non-alcoholic beers as well as beers brewed using locally sourced raw materials.

Enzymes are enabling factors for brewers to meet this demand.

EU

Enzymes are essential to produce beer. The enzymes (endogenous) occur naturally in malt. To optimize efficiency, the use of enzymes (exogenous) for brewing was introduced half a century ago. Today, industrial enzymes are applied throughout the brewing process. For the brewing sector to remain competitive, innovation to support development of enzymes continues and is important to both improve efficiency and broaden the use of local raw materials other than malt.

Enzymes for yield improvement and diversification in oils and fats production

The vegetable oils and fats processing industry is a sizeable and highly specialized industry where oils from crops like soybean and rapeseed are converted into a broad range of fats and oil products that are used either directly by consumers or used in the food industry.

Enzymes can be used in several processes in the industry to achieve the desired products. The enzymatic processes use less energy, water, and chemicals than the chemical processes that have traditionally been used in industry. Furthermore, the enzymatic processes produce less waste and generate an up to 2% higher yield of oil per ton of oil seed.

In vegetable oil refining, an enzyme is used, for instance, to prevent salad oils from getting rancid with time. Enzymes can also be used to convert vegetable oil into trans fat-free margarine and to produce specialty fats for bakery, confectionery, and dairy products, and for infant nutrition.

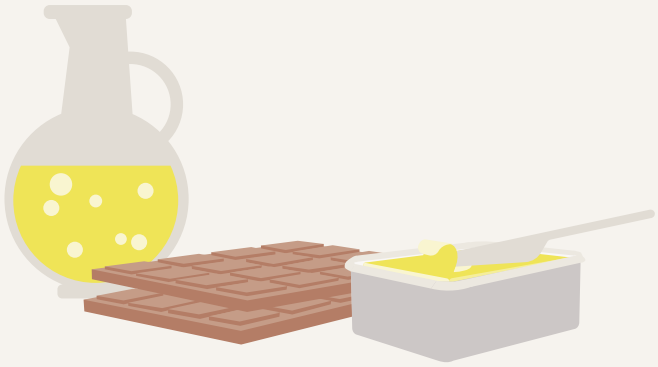
This contributes to the EU's Farm to Fork Strategy on

Climate
Energy and crude vegetable oil savings reduce pressure on the climate because greenhouse gas emissions are reduced during production of oil seeds and processing of the vegetable oils.

Biodiversity on land
Crude vegetable oil savings, achieved by yield improvements, is a benefit to biodiversity on land because less land is needed to produce oil seeds.

Health
High trans-fat intake increases the risk of coronary heart disease etc. Avoiding trans fats in margarine with the use of enzymes benefits population health.

Competition
Enzymes are biological tools in vegetable oil processing industry's toolbox. They can be used to make processing more efficient, and they can be used to produce an increasing number of specialty oils and fats with better health properties or mouthfeel.



Enzymes are used in multiple processes in the oils and fats processing industry. For instance, to produce cooking oil and margarine and to produce specialty fats, for instance, for chocolate.

EU

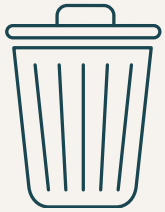
Enzymes have been used in the oils and fats industry for decades, but many industry players are still using chemical-based processes that are reliant on fossil-fuel inputs. New enzymatic solutions for the oils and fats industry are continually being deployed and provide the potential to significantly reduce the reliance on chemical and fossil inputs to the processes. Much like the evolution we have already seen in grain processing industry. See section about "Enzymes for starch, protein, and sweetener production"(Page 17).

Enzymes for better meat and fish-meat utilization

It can be difficult to utilize the meat that remains on bones in the fish industry and at slaughterhouses, and substantial amounts of valuable meat protein is wasted or utilized as feed for animals instead of food for humans.

Enzymes can be used to convert the meat on the bones into a protein rich broth, which can be used to add flavor and nutrients to pates, soups, bullions, sausages etc.

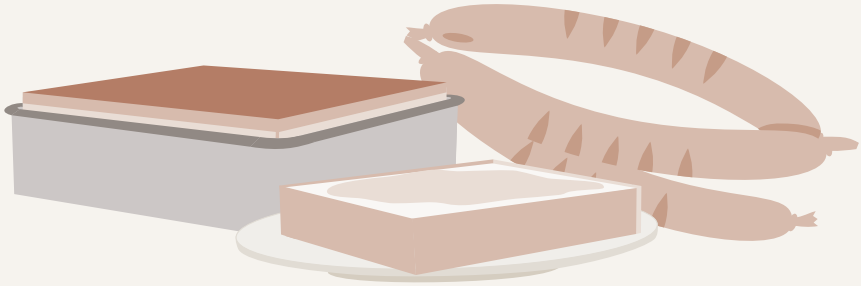
This contributes to the EU's Farm to Fork Strategy on



Food waste
Food waste is reduced because the meat left on the bones is upgraded and used for human consumption and not as a low-value animal feed supplement.

Health
Fish and meat protein broth has a savory flavor. Adding protein broth to processed food products enriches the taste and reduces the need for salt as a flavor enhancer. Excessive salt intake has a negative effect on public health.

Competition
Using enzymes in the fish industry and slaughtering industry adds more valuable products to the producers' portfolio. This can benefit these industries' return and thereby their competitiveness.



Protein broth can be used to add flavor to products such as pates and sausages and reduce the need for salt.

EU

Enzymes have been used to produce protein broth for decades in the EU. New enzymatic pathways to high-value products are developed these years. Examples include omega-3 fatty acids and "bio-active peptides".

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Appendix 1: Schematic overview of biosolutions' contribution to the EU's Farm to Fork Strategy

Table A1-1: Main environmental and health benefits that biosolutions offer to the EU's Farm to Fork Strategy

Item in Farm to Fork Strategy	Biosolution for...											
	Agri-culture	Biological pest managem.	Animal nutrition	Aqua-culture	Baking	Dairy	Starch	Plant-based protein	Wine and juice	Brewing	Oils and fats	Meat
Reduce consumption of **energy**	✓				✓		✓			✓	✓	
Reduce impact on **climate**	✓		✓		✓	✓	✓	✓		✓	✓	
Reverse loss of **biodiversity**	✓		✓	✓	✓	✓		✓	✓	✓	✓	
Reduce **antimicrobials** for farmed animals by 50% in 2030			✓					✓				
Reduce **pesticides** by 50% in 2030		✓						✓				
Sustainable **livestock** farming			✓									
Strengthen **resilience** of food system	✓			✓				✓				
25% **organic farming**								✓				
Healthier diets					✓	✓					✓	
Reduce **food waste**					✓							✓

Table A1-2:
Main competition-related benefits that biosolutions offer to the EU's Farm to Fork Strategy

Competition parameter	Biosolutions for...											
	Agri-culture	**Biological pest managem.**	**Animal nutrition**	**Aqua-culture**	**Baking**	**Dairy**	**Starch**	**Plant-based protein**	**Wine and juice**	**Brewing**	**Oils and fats**	**Meat**
Improve yield in production	✓		✓	✓			✓		✓		✓	
Enable use of a broader range or raw materials			✓		✓			✓		✓		✓
Reduce raw material and energy expenses etc.			✓	✓	✓	✓	✓	✓	✓	✓	✓	
Simplify processing							✓		✓	✓	✓	
Make **better** quality products		✓			✓	✓	✓	✓	✓	✓	✓	
Enable **new** products					✓	✓	✓	✓		✓	✓	✓

Appendix 2: Gene modification – a tool to make biosolutions safe and efficient

Enzymes and microorganisms can be produced with and without gene modification of microorganisms.

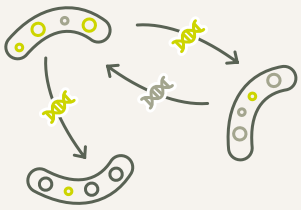
Genetic modification is used because it

- **Makes commercial biosolutions possible**
  Use of gene modification makes biosolutions efficient and keep production prices low. Many biosolutions would not be commercially viable if it were not gene modification
- **Makes biosolutions safe**
  Natural microorganisms are not suited for mass-production in a fermentation tank as they can have unwanted properties. Gene modified microorganisms' DNA is well-known and unwanted properties such as pathogenicity are eliminated.
- **Reduces environmental impact**
  Efficiency improvements achieved by gene modification are beneficial for the environment because less energy and raw materials are used in production.

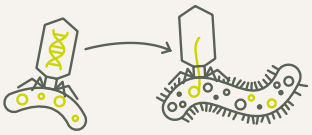
Transfer of genetic material is not a human invention

Microorganisms are constantly exchanging genes in nature to increase their ability to grow and survive. Gene exchange can happen between closely related microorganisms as well as between different types of microorganisms.

In nature



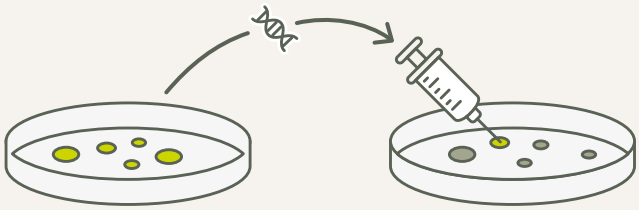
Closely related microorganisms are constantly exchanging genes to share capabilities and increase chance of survival and growth.



In rare and cases, a virus can pick up genetic material in one organism and transfer it to a different organism.

Non-beneficial genetic material will soon be deleted or disappear as part of the natural selection process. Genetic exchange processes are random and microorganisms with the best fitted genes will survive.

In the laboratory

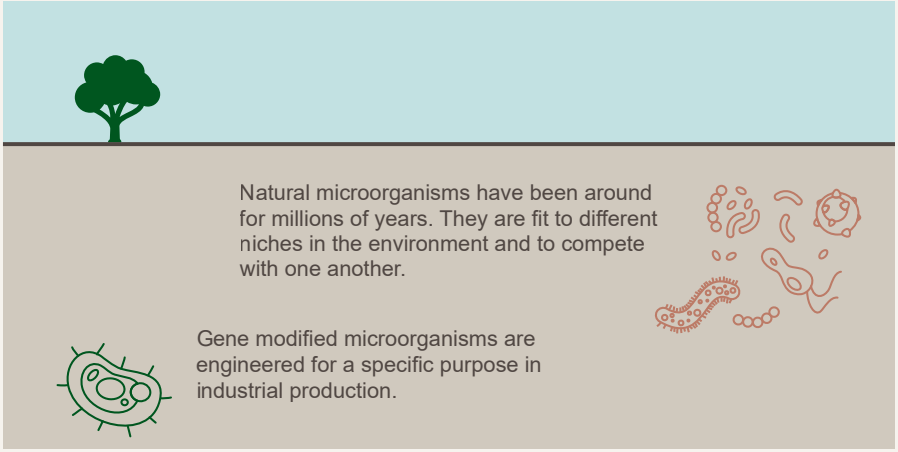


In modern biotechnology we take benefit of microorganisms' genetic flexibility. We use the nature's own genetic tools to copy and paste beneficial genes and to delete disadvantageous genes. The process is controlled and aim at creating organisms that can benefit human needs.

The gene modification that humans do in the laboratory is a controlled copy of what is already happening in nature.

Gene modified microorganisms are not fit to survive in nature

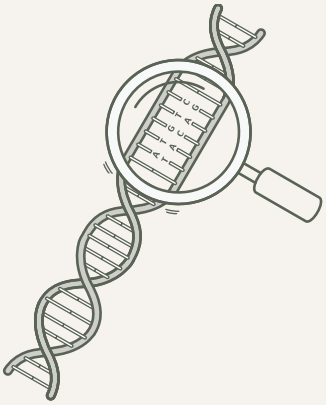
Whether it is in natural waters or in the soil, a gene modified organism will be met by fierce competition from other microorganisms and have little chance to find a niche to survive in.



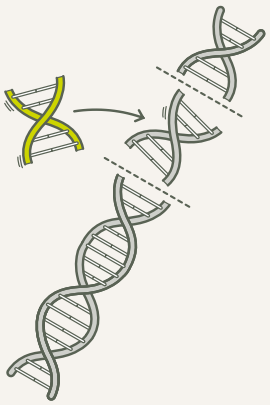
Gene modified micro-organisms are likely to have a short life in the environment because it is not a competitive advantage to be optimized for industrial use. Otherwise, this property would have developed naturally a long time ago during evolution.

How is gene modification controlled?

During gene modification wanted properties of an organism are enhanced and unwanted properties are eliminated. Wanted properties could be a higher expression of a specific enzyme. Unwanted properties of a microorganism could be if the microorganism were pathogenic. Before and after the gene modification, the genome is mapped using gene sequestration to ensure process quality.



Genome is mapped using gene sequencing to identify wanted and unwanted properties of the microorganism.



Unwanted properties of a microorganisms are removed, and desired properties are enhanced using precision genetic engineering for instance CRISPR technology

Quality of gene editing is controlled with gene sequencing before the microorganism leaves the laboratory

About Novozymes
Novozymes is the world leader in biological solutions. Together with customers, partners and the global community, we improve industrial performance while preserving the planet's resources and helping to build better lives. As the world's largest provider of enzyme and microbial technologies, our bioinnovation enables higher agricultural yields, low-temperature washing, energy-efficient production, renewable fuel and many other benefits that we rely on today and in the future. We call it Rethink Tomorrow.

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