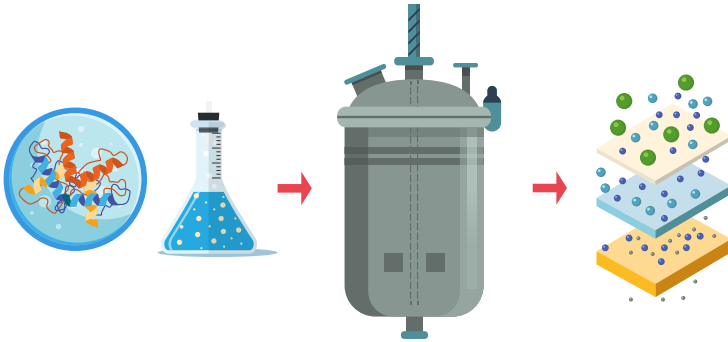


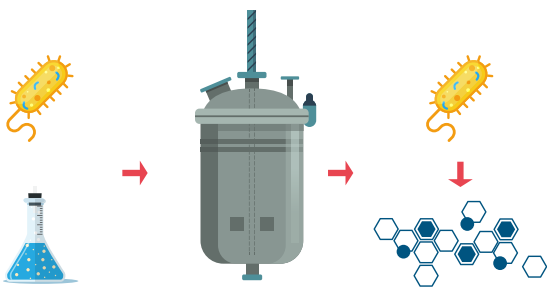
BIOMANUFACTURING CHEMICALS

Biomanufacturing encompasses the scale-up of processes that permit the consistent production of materials and ingredients, at a commercial scale. This represents an alternative to more traditional fossil-based processes for delivering chemicals as products. Benefits include the use of non-fossil feedstock like sugars, CO₂, waste, lower energy consumption, less GHG emissions and a better carbon footprint.

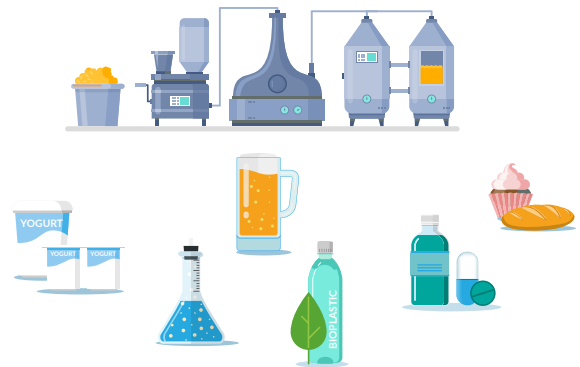


Upstream process focuses on the cultivation of microorganisms for mass-production, while downstream process involves the extraction and purification of the desired product from the cultured medium.

What is (industrial) fermentation?

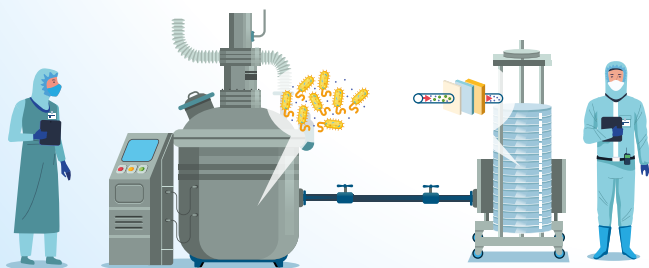


Industrial fermentation refers to processes using a living microorganism or enzyme, in particular bacteria, yeasts, algae, or fungi, to produce products of interest. The fermentation technique was used long before humankind discovered, or understood, microbes. It was adopted mainly to produce drinks containing the same active compound, ethanol, and for food preservation and was mainly empirical.

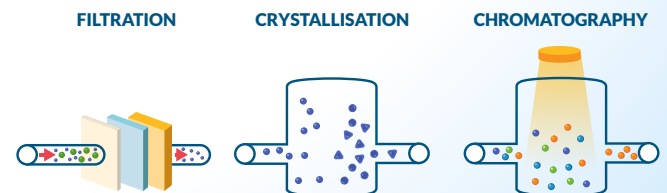


Thanks to the scientific advances of the last 4 decades, **fermentation is now a technology controlled by engineering** and is used in many sectors, such as food and feed, chemicals, pharmaceutical ingredients and biopolymer production.

How does fermentation work?



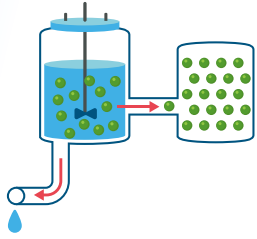
During the upstream processing of fermentation, various microorganisms such as bacteria, yeast, algae, or fungi are cultivated and nurtured within a carefully regulated environment. This entails supplying essential nutrients, oxygen, and ideal conditions conducive to their proliferation. Typically, the growth medium must comprise a carbon source, nitrogen source, water, salts, and micronutrients. Yeast extract serves as a provider of micronutrients and vitamins for fermentation media. **Due to the living nature of these organisms, the temperature utilised is notably lower compared to conventional chemical processes, thereby contributing to energy conservation.**



Once the microorganisms reach a desired concentration, the culture is ready for the downstream process.

The downstream fermentation processing encompasses the extraction and purification of the targeted product from the culture. This encompasses tasks like segregating the cells from the liquid medium, concentrating the product, and subjecting it to purification using an array of techniques like **filtration, crystallisation, precipitation, and chromatography.**

Purification and formulation are pivotal stages in the downstream processing of fermentation products. Here's an overview of some key steps involved:



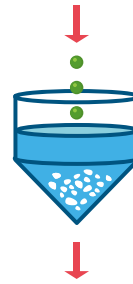
Harvesting:

Following fermentation, the culture broth is harvested before product recovery and isolation. This process entails separating microbial cells from the liquid medium.



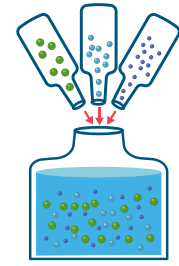
Centrifugation or Filtration:

The harvested mixture typically undergoes centrifugation or filtration to segregate cells from the liquid. This results in a cell-free supernatant containing the desired product.



Purification:

Various techniques, such as ultrafiltration or precipitation, may be employed to concentrate and partially purify the product. These methods effectively eliminate impurities and some by-products.

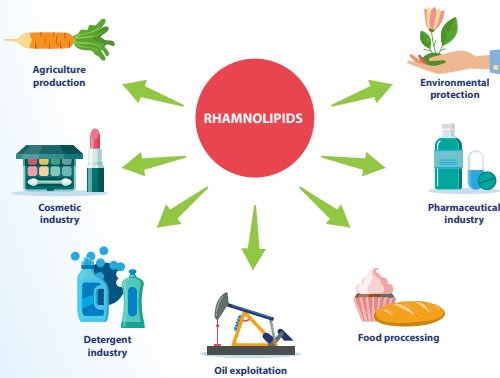


Formulation:

The purified product is then formulated to meet specific requirements, including concentration, stability, and desired characteristics. This phase may entail pH adjustments, addition of stabilisers, or other additives to enhance product properties. Subsequently, the product is packaged in a suitable form for storage, distribution, or further use.

Tiny cell factories in industrial bioreactors:

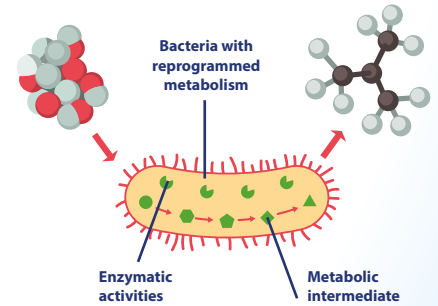
A number of chemical products are already biomanufactured, for example:



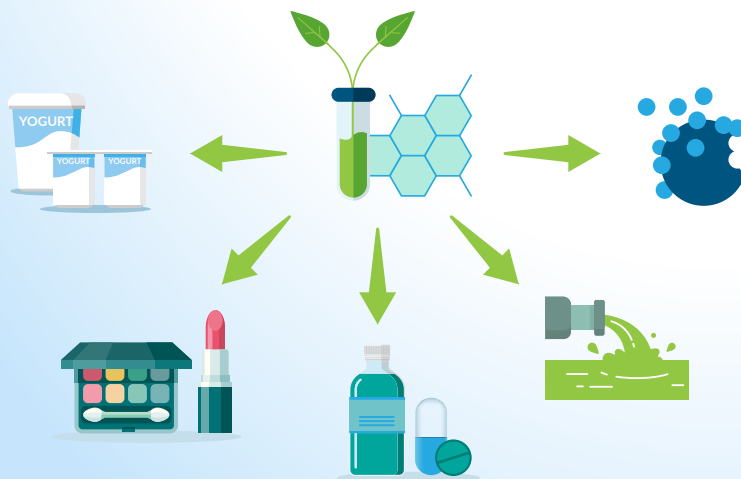
Biosurfactants: rhamnolipids (Evonik)



Isobutene (GBE)



Bio-(-)-Ambrox (Givaudan): fragrances



Biomufacturing has achieved significant scalability, initially penetrating pharmaceuticals, then cosmetics, and now expanding into nutrition and larger-scale chemical production. Technological advancements are now concentrated on refining processes, particularly through continuous processing, and broadening the range of feedstock used. **The potential market for such technology approaches nearly 1 trillion dollars globally.** Welcome to the era of biomufacturing!