



PRECISION FERMENTATION

Yeast plays a crucial role in the burgeoning field of precision fermentation, an old but revolutionary biological technique to produce valuable biomolecules with smaller environmental footprints.



ROLE OF YEAST

In precision fermentation, **yeast acts as a biological factory** via the controlled cultivation of enhanced modified yeast cells to produce specific compounds of interest in the food & feed sectors such as protein, amino acid, fatty acid, flavor molecule, vitamin, pigments, enzymes or even in the pharmaceutical sector. At the end of the cultivation phase, the desired resulting compounds are filtered out, separating them from the yeast that produced them.

Several microorganisms can be used for precision fermentation including algae, bacteria or fungi but yeast offers several advantages for this purpose: :

- **Rapid growth rate** in comparison to other microorganisms.
- **Efficient fermentation:** Yeast readily consumes sugars as its primary energy source, efficiently converting them into desired products during fermentation.
- **Well-characterized genetics and metabolism:** Scientists have a deep understanding of yeast's metabolic pathways, enabling them to optimize production.
- **Predictable and scalable:** Yeast growth and fermentation processes are well-established, making it a predictable and reliable platform, enabling high-volume production of targeted molecules.
- **Safe and generally regarded as safe (GRAS):** Many yeast species have a long history of safe use in food and beverage production.
- **Cost-effectiveness:** With advancements in fermentation technology and strain optimization, the cost of producing biomolecules through yeast is becoming increasingly competitive.

Depending on the desired end-product, precision fermentation can offer many benefits: elimination of the need for animal extraction (like for insulin or rennet), shift from a chemical synthesis to a biological synthesis. This bio-manufacturing process is more resource efficient, releases fewer greenhouse gas emissions and has less environmental impacts.

Yeast as a biological factory has a **wide range of applications in precision fermentation:**

- **Food and drinks:** Production of animal-free dairy proteins (casein and whey), meat substitutes, and specialty ingredients like flavors and sweeteners¹.
- **Specialty chemicals:** Production of fragrances, pigments, and enzymes for food, feed or textiles.
- **Pharmaceuticals:** Manufacture of recombinant insulin, vaccines, and therapeutic proteins.
- **Biofuels and biochemicals:** Development of sustainable biofuels and biochemicals to reduce reliance on fossil fuels.

¹ L.J.G. Hoppenreijns, A. Annibal, G.J.C. Vreeke, R.M. Boom, J.K. Keppler, Food proteins from yeast-based precision fermentation: Simple purification of recombinant β -lactoglobulin using polyphosphate, Food Research International, 2024, <https://doi.org/10.1016/j.foodres.2023.113801>



SPECIES OF YEAST USED

- ***Saccharomyces cerevisiae*** (Baker's yeast), the heart of brewing and baking, is a popular choice due to its established industrial fermentation protocols and vast scientific knowledge base.
Applications: Production of human insulin, essential amino acids, and flavors like vanillin.
- ***Pichia pastoris* (*Komagataella pastoris*)** is gaining traction due to its ability to produce complex proteins with proper folding and glycosylation patterns.
Applications: Production of biopharmaceuticals like interferon alpha (used to treat some cancers) and components of spider silk for material applications.
- Other emerging yeasts are being explored for their specific metabolic strengths, such as:
 - ***Yarrowia lipolytica*** enables high lipid production.
 - ***Kluyveromyces lactis*** has a particular tolerance to harsh fermentation conditions.Applications: To explore the production of alternative fats and biofuels.



A SHORT HISTORY

Precision fermentation has been used for over 30 years. One of the earliest examples was the production of insulin in the 1970s using modified *S. Cerevisiae*, providing a solution for diabetic patients without having to extract insulin from cow or pig pancreases. The advent of genetic engineering techniques in the late 20th century paved the way for an increased use of precision fermentation with yeast. Since then, the field has witnessed rapid advancements, with the production of a large range of high-value products like essential amino acids, heme (the iron-containing molecule in red blood cells), enzymes, and even animal proteins such as milk proteins (caseins or whey).



KEY DATA

- The European precision fermentation ingredients market could experience a market growth of 43,6% CAGR (Compound Annual Growth Rate) between 2023 and 2030².
- Europe holds the largest market share of 40% of the precision fermentation market³:
 - By application, the dairy alternative segment contributed almost 60% of revenue share.
 - By micro-organism, yeast could represent the highest market share across 2023-2032.
- Precision fermentation significantly reduces the environmental footprint of food ingredient production. For example, yeast-based precision fermentation whey protein is more sustainable than **traditional milk-derived whey protein**⁴:
 - Using precision fermentation process to produce 1 kg of whey protein reduces greenhouse gas emissions by 91%-97%, as compared to 1kg of conventional dairy protein⁵.
 - Precision fermentation cuts blue water⁶ consumption by 96%-99%⁵.
 - Energy consumption is 30%-60% lower with precision fermentation⁵.
 - Precision fermentation requires up to 99% less land compared to conventional livestock farming⁵.



PROSPECTS AND INNOVATIONS

The future of precision fermentation with yeast is bright, with some exciting areas of development:

- **Machine learning-aided strain design:** Utilizing machine learning algorithms to accelerate the design and optimization of yeast strains for specific target molecules.
- **Consolidated bioprocessing:** Integrating multiple steps of the fermentation process for improved efficiency and reduced production costs.
- **Novel yeast platforms:** Exploring alternative yeast species with unique metabolic capabilities to expand the range of biomolecules that can be produced.
- **Data-driven and AI-based biomanufacturing:** Developing these cutting-edge technologies could reduce cost and time-to-market.

2. KBV Research (2023). Europe Precision Fermentation Ingredients Market Size, 2030. KBV Research. Available at: <https://www.kbvresearch.com/europe-precision-fermentation-ingredients-market/>

3. Precedence Research (2023). Precision Fermentation Market Size, Trends, Growth, Report 2032. Available at: <https://www.precedenceresearch.com/precision-fermentation-market>

4. FAO (UN Food and Agriculture Organization) (2013). A global life cycle assessment Greenhouse gas emissions from ruminant supply chains. Available at: <https://www.fao.org/4/i3461e/i3461e.pdf>

5. Science Media Centre. (2024). 'Precision fermentation' and the future of NZ food - Expert Reaction. Available at: <https://www.sciencemediacentre.co.nz/2024/05/16/precision-fermentation-and-the-future-of-nz-food-expert-reaction/>

6. "Blue" water is water that transfers rapidly into rivers, lakes and groundwater. Blue and green water. INRAE Silva Joint Research Unit. Available at: <https://appgeodb.nancy.inra.fr/biljou/en/fiche/eau-verte-eau-bleue>

