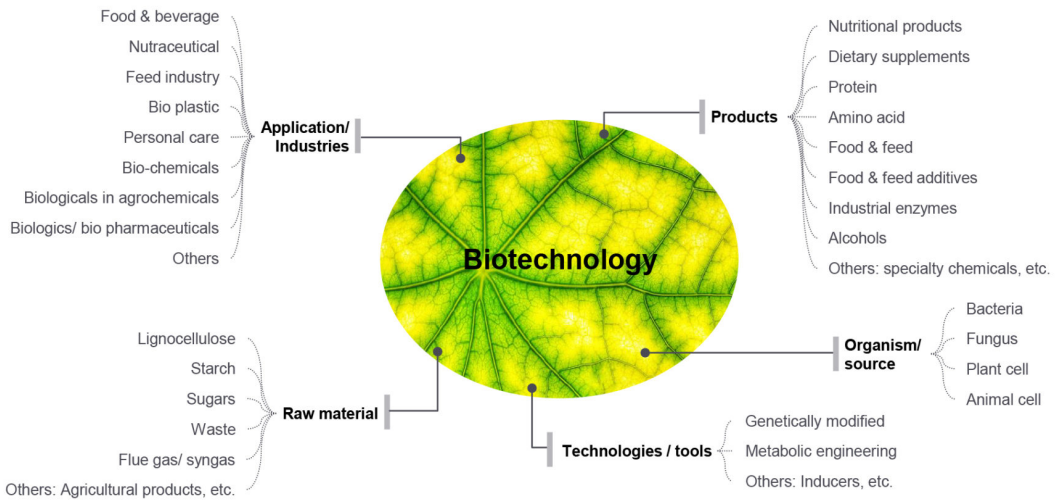
Biotechnology Opportunities and Challenges within Chemical Process Industry

Biotechnology is the application of engineering and scientific principles to biological agents for the manufacturing and/or processing of materials. It has applications in multiple industries such as chemicals & materials, pharmaceuticals, energy, agriculture, food & feed, among others.

The organisms are the core component of biotechnology as they contain necessary metabolic pathways and enzymes. These organisms convert substrates / raw materials to use chemicals that can be used in applications through metabolic pathways. It can be re-engineered at the genetic level using genetic engineering to maximize the output of desired product.

Exhibit 1 shows the taxonomy of biotechnology in terms of raw materials, organisms used, technologies used, products, and different applications.

EXHIBIT 1: Taxonomy in biotechnology



Source: FutureBridge Analysis

A variety of raw materials including cellulosic materials, sugar-based substrates, waste, industrial flue/syngas can be used. In certain cases such as amino acids, proteins, and other pharma products; very specific and purified raw materials are used. In some cases, gene inducers are used to

induce the particular metabolic pathway to produce the desired pathway.

Applications of biotechnology in different industries ranging from cosmetics to agrochemicals where few products are directly used and few are further processed to get the desired compound for any particular application. Few products in food, drug, and agrochemical industries need regulatory approvals to be used as they may have an impact on the environment and human population. Bioplastics are having greater traction in recent years owing to low toxicity and low carbon profile as compared to crude oil-based counterparts.

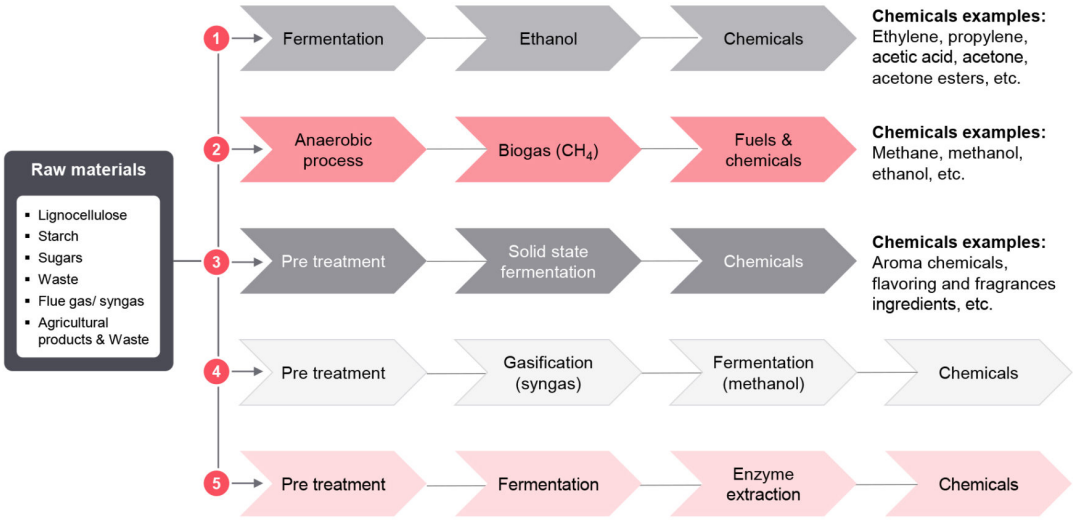
Biotechnology routes/pathways to produce chemicals & materials

Depending on the raw materials and developed technologies in terms of microorganisms' ability to process the raw materials, there are multiple pathways to produce chemicals and materials using biotechnology routes.

Few raw materials cannot be directly used for fermentation as microorganisms may not have the required enzyme or metabolic pathway to process it. It can be genetically engineered to gain that ability however, pre-processing is a better option for processing those raw materials.

Exhibit 2 shows some of the different pathways to achieve chemicals and material manufacturing using biotechnology. Multiple fermentation methodologies can also be used such as liquid fermentation where a fermenter filled with nutrients is used while in solid-state fermentation, solid form raw materials are used in maintained environmental conditions of temperature and pressure. In terms of oxygen requirements, there are two types of processes: Aerobic and anaerobic. Based on the microorganism and expected output, these processes are decided.

EXHIBIT 2: Various pathways to achieve chemicals and material manufacturing using biotechnology



Source: FutureBridge Analysis

Furthermore, few of the processes use microorganisms directly in the system, and few other use enzymes extracted from microorganisms in the process. Based on a number of steps the system is selected. For instance, if there are multiple steps involved to process raw material for the manufacture of chemical then live microorganism is preferred as metabolic pathways are involved in it. On the other hand, if any particular single step is involved then enzymes extracted are used. For example, to produce chitosan (a material used in multiple pharma products) can be produced using the chitin deacetylase enzyme which removed the acetyl group from chitin.

Chemicals & materials produced through biotechnology route

In the chemicals & materials industry, biotechnology is used to manufacture a myriad of chemicals that can be building blocks for high-demand chemicals or can be directly used in various applications.

The value chain complexity of the products differs based on the number of steps involved to get the final desired products. It also depends highly on the type of raw material being used. The value chain includes multiple physical and chemical processes after or prior to fermentation. For instance, lactic acid can be produced directly from the fermentation of sugars using lactic acid bacteria and then further polymerized to polylactic acid (PLA) which is very used in the packaging industry. Another pathway could be gasification of the waste to produce syngas and then fermentation using microbes to produce different chemicals

List of majorly produced biotechnology-based products in the chemicals & materials industry:

- **Surfactants** (microbial & plant surfactants)
  - Bio-degradability, low human toxicity, and lower ecotoxicity
  - Cost competitiveness is the major barrier to the adoption
- **Plastics and polymers** (bio-PBT, Bio-PP, PHA, PLA, etc.)
  - Biodegradability, recyclability, low ecotoxicity are the drivers
  - Companies have made significant investments into developing plastics and polymers considering the harmful impact of crude based plastics
  - Although these plastics match the technical properties of their counterparts, significant R&D needs to be done to reduce their production costs
- **Cosmetics** (botanical extracts, vegetable oils, solvents, succinic acid, etc.):
  - Low human toxicity and low GHG emissions are the drivers for biotech products in the cosmetics industry.
  - These ingredients are strictly regulated as they directly come in contact with humans.
  - Cost parameter is not the constraint for this industry
- **Lubricants** (fatty acid esters, oleate, base oil, thickeners, etc.)
  - Environmental concerns of the crude oil-based lubricants are the leading drivers
  - Biodegradability, low human toxicity, low ecotoxicity, low GHG, and recyclability are advantages offered
  - Low-temperature stability and low oxidation resistance are the barriers
- **Agrochemicals** (bio-fungicides, bio-insecticides, biological seed treatment, etc.)
  - Biological products are gaining more traction due to low or no toxicity to the environment
  - Frequency of application and consistent performance are major challenges with these products
  - These products are highly regulated and active ingredients need to be registered which is a long and expensive process
- **Adhesives, paints & coatings** (Bio-ethyl acetate, dimethyl succinates, bio-based polyols, etc.)
  - Low ecotoxicity is the trend in these industries where solvents are the major products and companies are innovating in order to find alternatives such as enzyme-based products
  - Performance parameters such as desired appearance, east of

application, durability, and drying times are important to enhance the adoption

- Price and performance are major barriers for large scale adoption of biotech products
- Others (FDCA, PEF, butanediols, butyl lactate, etc.)

EXHIBIT 3: Biotechnology barriers and sustainability drivers

Products	Major barriers for adoption	Sustainability drivers
Surfactants	▪ Cost competitiveness	
Plastics and polymers	▪ Cost competitiveness	
Cosmetic ingredients	▪ Concerns about functionality ▪ Cost competiveness ▪ Expensive process of switching	
Lubricants	▪ Low temperature stability ▪ Low oxidation resistance	
Agrochemicals	▪ Concerns about functionality ▪ Cost competiveness ▪ Expensive process of switching	
Adhesives, paints & coatings	▪ High cost of formulations ▪ Performance challenges	

Legend: Biodegradability, Low GHG, Low eco-toxicity, Low human toxicity

Source: FutureBridge Analysis

Biotechnology provides a sustainable way of manufacturing certain products that can be a good replacement for crude-oil-based chemicals and materials. However, it faces a few hurdles which is currently hampering the wide range of adoption of biotechnology in different industries.

What are the challenges?

- **Access to feedstock:** The feedstock used in biotechnology is especially based on agriculture output for which the biotechnology route has to compete with the food. For instance, corn is majorly used as raw material for bioethanol and also as a food ingredient.
- **Competition with established fossil industry:** All the chemicals and materials currently produced with fossil fuel as raw material. All the processes and production costs have been optimized for optimum profitability. With respect to biotechnology, it is hard to compete with established processes and systems in terms of cost and production capacity.
- **Regulatory barriers:** Regulations across regions are different with respect to the microorganisms used for the production. Manufacturing using genetically engineered organisms can lead to an imbalance in
- **Societal barriers:** The majority of the microorganisms need to be genetically engineered in order to get optimum production methods

with multiple raw material processibility. Certain groups in various regions such as Europe are against the usage of GMOs (Genetically modified organisms) in any of the aspects.

- **Markets, finance, and investment:** biotechnology-based products need to compete with conventional products with respect to the final price at which it is being offered in the market. This price depends on the balance between market demand and production capacity to reach economies of scale. Also, players have already invested in the conventional chemical processes and are reluctant to move towards new investments unless ROI on conventional processes is achieved.

Outlook for biotech in C&M

The future of manufacturing is through bio-route where bio-based raw materials and/or biotechnological processes can be used to manufacture different chemicals and materials. The majority of the reason to move towards this is the sustainability advantages it offers such as:

- Bio-based raw materials are of low carbon footprint
- Biotechnological processes that reduce overall GHG emissions and also prevent usage of environmentally harmful chemicals in the manufacturing

Biotechnology is being used in various ways with respect to sustainability such as:

- **Bioplastics:** It can be used to produce certain bioplastics that reduce the overall carbon footprint of the end product with similar properties to its conventional counterparts.
- **Plastics degradation:** Certain companies are working to develop microorganisms that can degrade plastic and some are developing additives that aid the degradation.
- **Cultivated meat:** Lab-grown meat is a sustainable way to replace conventional meat that produces greenhouse gases and also uses a significant amount of water.
- **Biofertilizers and bio-pesticides:** Chemical fertilizers are one of the major factors impacting the environment and its components significantly. Chemical pesticides are also impacting the environment as well as human health significantly due to the presence of toxic chemicals in them. Biofertilizers and bio-pesticides offer a very good sustainable option to chemical fertilizers and pesticides as it does not release any toxic chemicals and usage microorganisms and botanical

extracts as active ingredients.

- **Construction materials:** Companies have developed certain bacteria that can repair the material when it suffers damage. Also, algae-based construction materials are being developed.
- **Cosmetics:** Companies are developing biotech-derived products that can be used in cosmetics such as skincare, haircare products, and marketing as sustainably produced materials.
- **Textiles:** Biotechnology can be used to produce biodegradable textiles that can be used in multiple products. Spider silk through fermentation, biodegradable materials for shoes, textile fibers from algae, and sustainable textile dyes from fermentation are a few examples.

Conclusion

Biotechnology offers multiple advantages in terms of reducing dependence on crude-based chemicals thus lowering carbon footprints, improving the sustainability of the products as it is easy to process them to reuse, recycle or degrade, in some cases lower production cost.

The regulatory scenarios in major regions are pushing the move towards biotechnological processes for the advantages it offers. The majority of the chemical and material manufacturers are moving towards it by their own R&D or with the help of collaborations.

There are barriers with respect to investments, economies of scale, and cost competitiveness for biotechnological products. However, changing dynamics in global markets coupled with technological advancements through R&D supported by regulations for sustainability will be the drivers for biotechnology.

References

1. OECD biotechnology update
2. The Bioscience Economy
3. Ten Ways Biotechnology Makes the World More Sustainable
4. Accelerating innovation and uptake of bio-based products

Acronyms:

PEF: Poly (ethylene 2,5-furandicarboxylate)
FDCA: 2,5-Furandicarboxylic acid
PHA: Polyhydroxyalkanoates
PBT: Bio-polybutylene terephthalate)