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Challenge based lecture

Session 1:

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Question

Briefly explain fermentation

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Fermentation

Definitions

“The chemical breakdown of a substance by bacteria, yeasts, or other microorganisms”

“Fermentation, chemical process by which molecules such as glucose are broken down anaerobically”.

“Fermentation is a biochemical process that breaks down organic materials into simpler compounds, such as alcohols, organic acids, and carbon dioxide. It is carried out by microorganisms, such as bacteria, yeast, or filamentous fungi, in the absence of oxygen.

Fermentation is essential for living organisms, especially microorganisms, as it is their primary way of producing energy. Humans have used fermentation since the Neolithic period to develop many products, including foods, medicines and fuel”

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Question

Name / discuss examples of fermentation in foods

Fermentation – Cheese

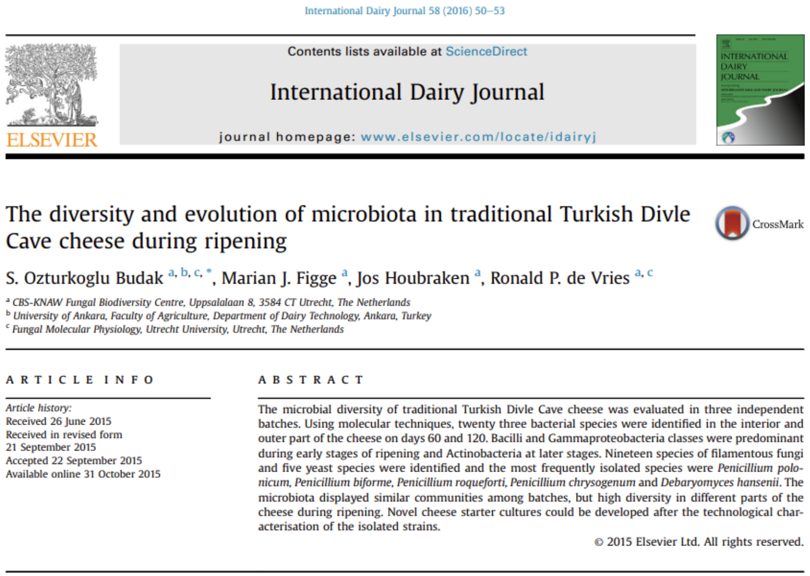
Role – acid production and flavour production

Steps

1. **Inoculate**: Lactic acid bacteria and rennet are added to milk in a vat.
2. **Curdle**: The lactic acid and rennet cause the milk to curdle, separating the curds and whey.
3. **Drain**: Excess liquid is drained away.
4. **Salt, press, and ripen**: The cheese is salted, pressed, and ripened

Did you know – during ripening, bacteria, yeast and fungi can play a critical role in flavour development in cheese. Furthermore, the microorganisms are often location specific, giving rise to unique flavour profiles. Check out the paper for more information.

https://www.sciencedirect.com/science/article/pii/S0958694615001892



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The diversity and evolution of microbiota in traditional Turkish Divle Cave cheese during ripening

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ABSTRACT
The microbial diversity of traditional Turkish Divle Cave cheese was evaluated in three independent batches. Using molecular techniques, twenty three bacterial species were identified in the interior and outer part of the cheese on days 60 and 120. Bacilli and Gammaproteobacteria classes were predominant during early stages of ripening and Actinobacteria at later stages. Nineteen species of filamentous fungi and five yeast species were identified and the most frequently isolated species were *Penicillium polonicum*, *Penicillium biforme*, *Penicillium roqueforti*, *Penicillium chrysogenum* and *Debaryomyces hansenii*. The microbiota displayed similar communities among batches, but high diversity in different parts of the cheese during ripening. Novel cheese starter cultures could be developed after the technological characterisation of the isolated strains.

Fermentation in action

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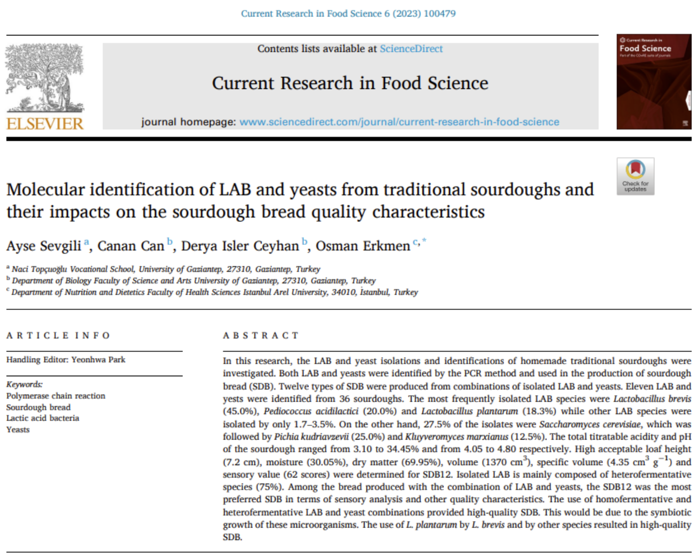
Fermentation – Bread

Role – Carbon Dioxide production

Fermentation is a biological process that occurs in bread dough when yeast and other microorganisms consume sugars and produce carbon dioxide and other compounds.

This process causes the dough to rise, contributing to the texture of the bread. Furthermore, it contributes characteristic flavor.

https://www.sciencedirect.com/science/article/pii/S2665927123000473#sec3



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Molecular identification of LAB and yeasts from traditional sourdoughs and their impacts on the sourdough bread quality characteristics

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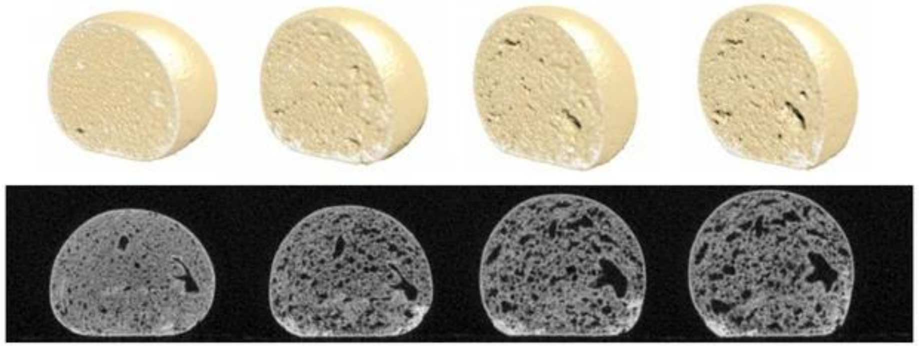
ABSTRACT

In this research, the LAB and yeast isolations and identifications of homemade traditional sourdoughs were investigated. Both LAB and yeasts were identified by the PCR method and used in the production of sourdough bread (SDB). Twelve types of SDB were produced from combinations of isolated LAB and yeasts. Eleven LAB and yests were identified from 36 sourdoughs. The most frequently isolated LAB species were *Lactobacillus brevis* (45.0%), *Pediococcus acidilactici* (20.0%) and *Lactobacillus plantarum* (18.3%) while other LAB species were isolated by only 1.7–3.5%. On the other hand, 27.5% of the isolates were *Saccharomyces cerevisiae*, which was followed by *Pichia kudriavzevii* (25.0%) and *Kluyveromyces marxianus* (12.5%). The total titratable acidity and pH of the sourdough ranged from 3.10 to 34.45% and from 4.05 to 4.80 respectively. High acceptable loaf height (7.2 cm), moisture (30.05%), dry matter (69.95%), volume (1370 cm^3), specific volume (4.35 $cm^3 g^{-1}$) and sensory value (62 scores) were determined for SDB12. Isolated LAB is mainly composed of heterofermentative species (75%). Among the bread produced with the combination of LAB and yeasts, the SDB12 was the most preferred SDB in terms of sensory analysis and other quality characteristics. The use of homofermentative and heterofermentative LAB and yeast combinations provided high-quality SDB. This would be due to the symbiotic growth of these microorganisms. The use of *L. plantarum* by *L. brevis* and by other species resulted in high-quality SDB.

Fermentation in action ↑



0 min | 20 min | 50 min | 80 min

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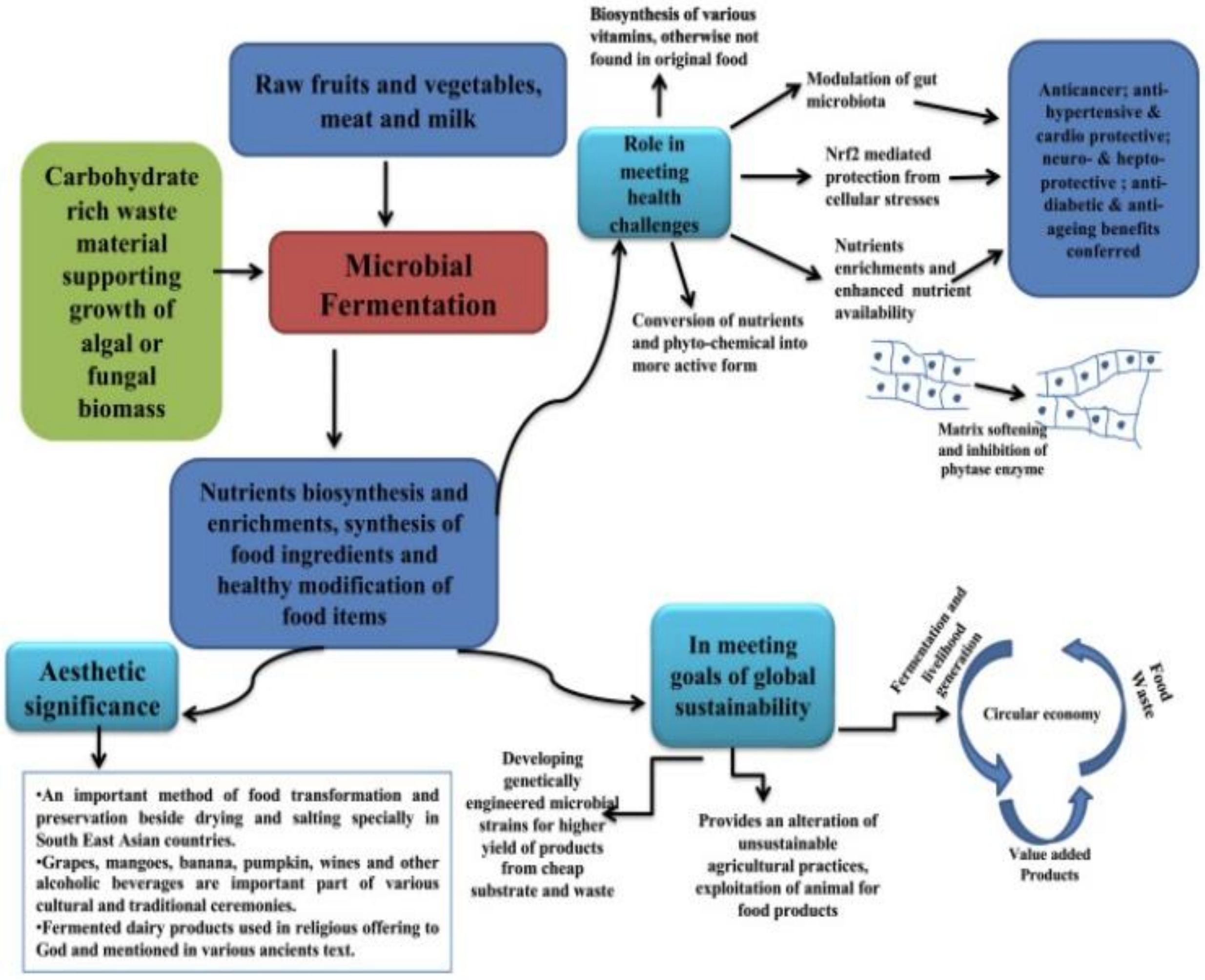
Question

How can fermentation help in producing more sustainable and nutritious ingredients?

Discuss this diagram and consider the potential of fermentation.

Consider

- Fermented foods and health
- Fermented foods and the microbiome.
- Fermentation as a tool in valorization.



https://www.sciencedirect.com/science/article/pii/S0168160522001374#f0005

Question

Are you familiar with companies using fermentation to develop a new range of food products.

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A new wave of fermented products

— HOW IS EVERY EGG MADE?

In a breakthrough for the culinary world, our EVERY Egg is a liquid egg made without the hen. Instead of chickens, we use precision fermentation to create real animal protein that is equivalent to the key protein found in a hen's egg. In a process reminiscent of time-honored brewing traditions, we combine a special yeast — found on a California black oak tree in the 1950s — with sugar and water in a fermentation vessel. But instead of brewing beer, our yeast brew egg protein. We then separate our yeast, leaving us with a clarified broth teeming with real egg proteins. We then add beneficial plant-based ingredients to our egg proteins to craft our liquid EVERY Egg.

REAL ANIMAL PROTEIN WITHOUT THE ANIMAL

The world's first animal-free egg white protein that is nature-equivalent to chicken egg white protein - enabling a transition to sustainable, animal-free products without compromise in taste or functionality.

FUNCTIONS LIKE AN EGG

Just like a chicken egg white, EVERY EggWhite™ has similar protein content and all nine essential amino acids. It delivers on foaming, whipping, gelling, and binding capabilities and can easily be used as a 1:1 replacement across many of the same applications one would use eggs in: cakes, cookies, bread, protein bars, plant-based meats, pasta, and more.

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PERFECT DAY

Biology as a service

- Perfect day genetically engineered microbiota by including the DNA sequence responsible for producing whey proteins in cow's milk.
- The microbiota are grown in tanks with a sub straight (sugar) which is converted into the milk protein whey.
- The approach uses recombinant technology.
- Once extracted and separated from the microbiota, the protein is dried and functions as an ingredient similar to whey derived from milk.

Thank you

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Optimised fermentation process

Session 2:

Fundamental principles of traditional and optimised fermentation, and safe & sustainable production practices

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Fundamental principles of traditional and optimised fermentation

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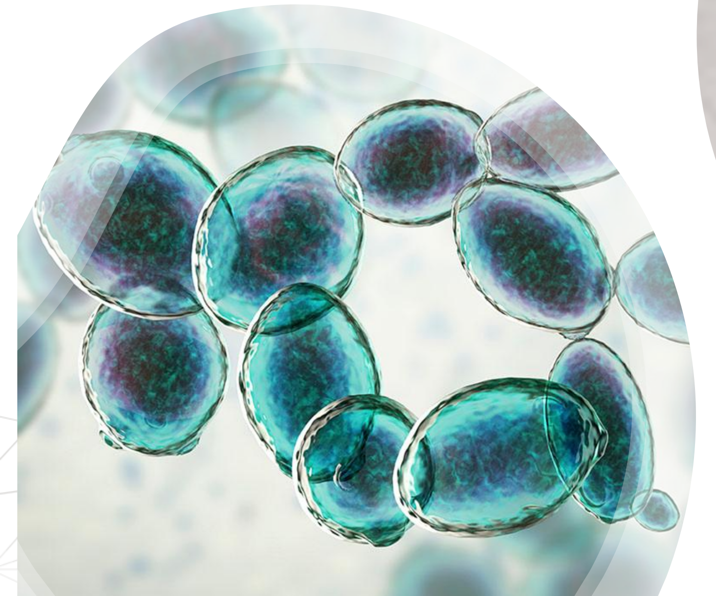
Fermentation

Traditional Fermentation

Shaped by natural processes with minimal input or control from the operator. Examples would include traditional farmhouse cheeses or homemade sauerkraut.

Optimised fermentation

Often conducted in a bioreactor to give a higher level of control and precision over the environment (temperature, pH, light, atmosphere), leading to a more consistent product. The use of filters prevents contamination and precise control allows scale up of production.



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Use of cultures – from wild to pure (1/2)

- Microorganisms are the powerhouse of fermentation.
- Traditionally wild cultures would have played a significant role in the fermentation of different foods.
- Less prevalent today, however, some products such as sauerkraut rely on cultures present on the cabbage while certain types of cheeses, such as those matured in caves rely on wild cultures for flavour development. Lambic beer is naturally fermented using wild yeasts
- In recent decades there has been a move towards more specific strains for fermentation, the reasons vary but include flavour profile, speed and product attributes. saccharomyces cerevisiae is commonly used in beer production while Lactobacillus bulgaricus and Streptococcus thermophilus are commonly used in yoghurt.

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Use of cultures – from wild to pure (2/2)

Cell activities are critical to the successful completion of fermentation, these include;

Anaerobic metabolism;

- Occurs in the absence of oxygen, microorganisms such as yeasts and bacteria breaking down organic compounds such as carbohydrates.

Glycolysis

- The production of pyruvate following the breakdown of glucose

Pyruvate Conversion

- The conversion of pyruvate into different end products including; ethanol, lactic acid or organic acids (propionic acid, butyric acid)

NAD+ Regeneration

- When NAD+ is converted to NADH as part of fermentation (glycolysis), it needs to be converted back to NAD+ to continue fermentation.

Yield (Energy).

- Fermentation is less efficient than aerobic respiration.

Environmental Control

Cultures have optimum ranges for a series of environmental conditions, providing these conditions increases fermentation rate and output.

Light

- Important to microalgae who require a light source to photosynthesis.

pH

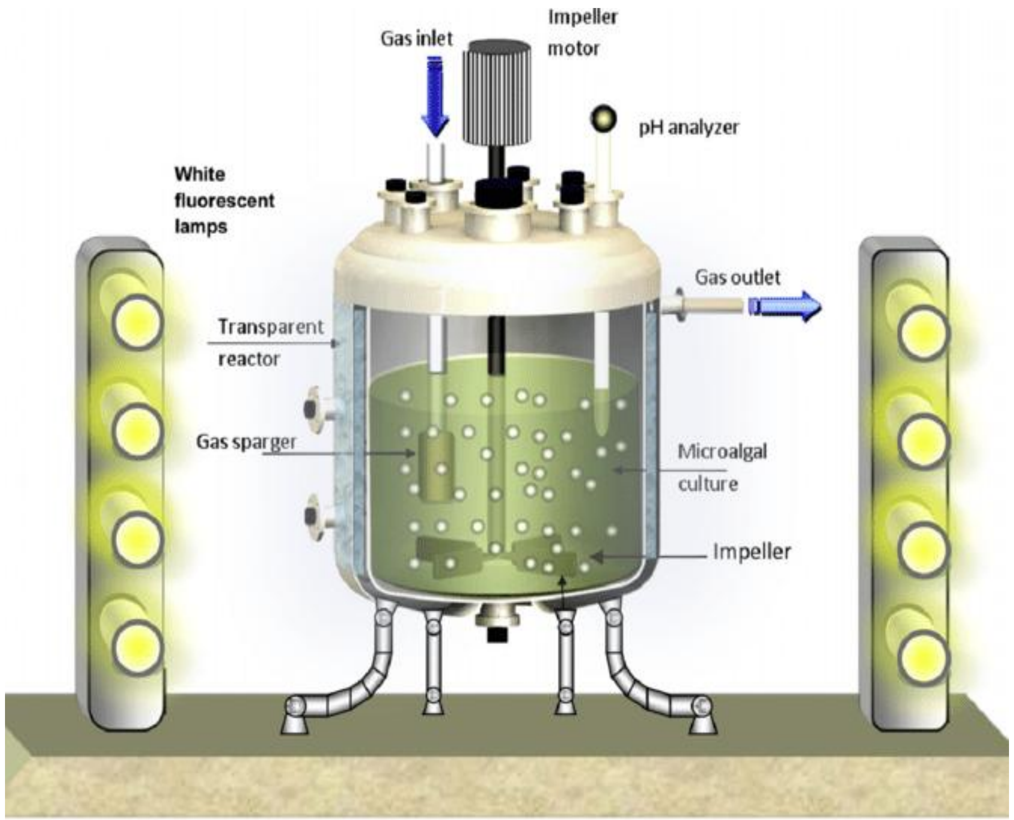
- Cultures have an optimized pH range for metabolism. Outside of this range is potentially detrimental to the culture and can therefore significantly slow or halt fermentation. Bioreactors often have pH probes built in.

Temperature

- Cultures can become heat stressed, leading to possible by products, reduced fermentation rate or cell death. Reactors are often jacketed to control temperature to one degree ℃

Dissolved oxygen

- Many bioreactors monitor for dissolved oxygen and carbon dioxide to ensure sufficent levels for respiration and to avoid toxicity. This can be controlled by bubbling in the required gas via a sparge ring.



Enhanced process efficiency

The use of fermenters equipped with sensors, probes, cell counting functionality and aseptic addition of growth media helps to provide the perfect environment.

This leads to;

- Increased yield
- Decreased fermentation time
- Optimised substrate use.
- Minimise contamination

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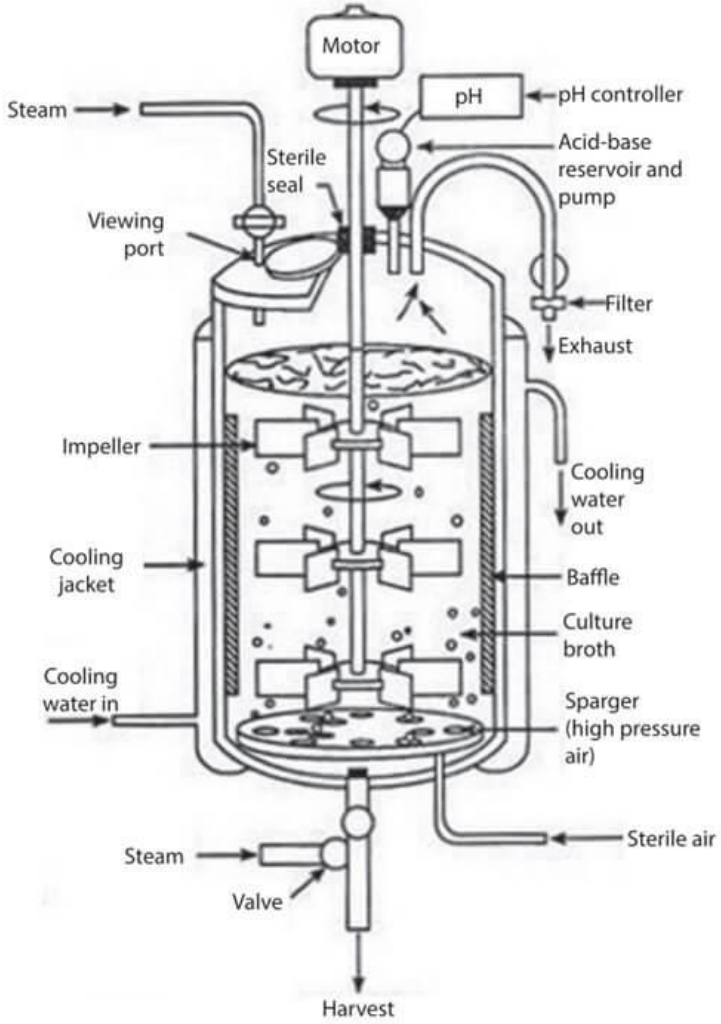
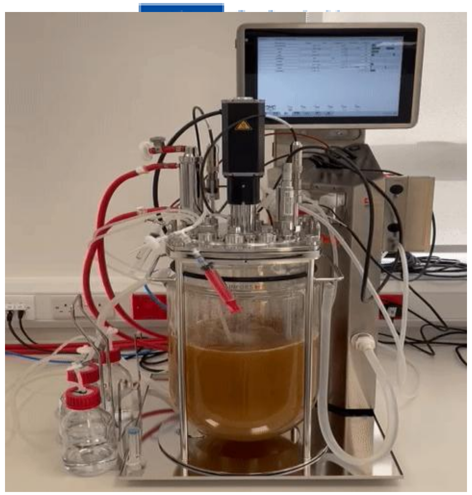
Bioreactors



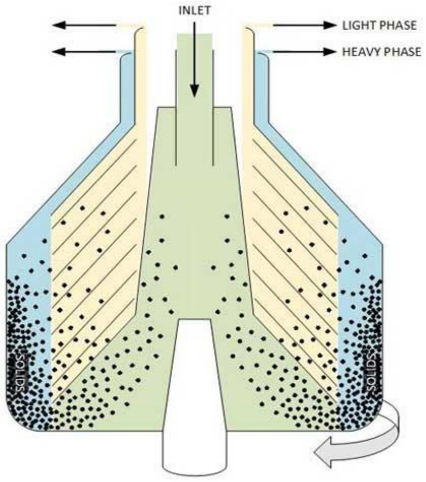


Downstream processing

Downstream can improve functionality and add value

Filtration

- Microfiltration, nanofiltration and ultrafiltration can all be achieved using membrane technology. This allows different fractions to be separated based on molecular weight.
- Reverse osmosis can be used to remove or alter the mineral profile of liquid formulations.



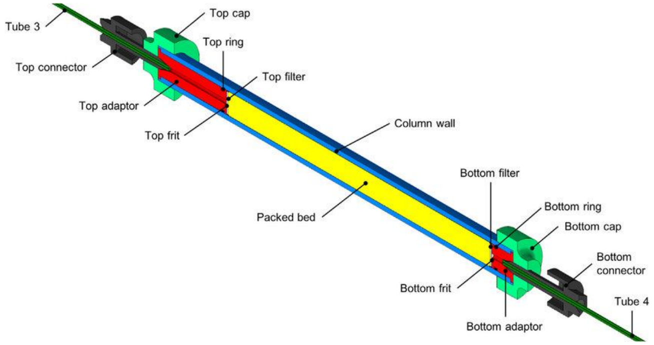
Disc Stack Centrifuge Bowl

Centrifugation

- Can separate different products from fermentation based on their densities. It can remove solid particles for clarification, isolation of lipid fractions.

Extraction

- This can include physical disruption of cells to release valuable components. It often includes other technologies such as adsorption methods, evaporation and filtration.



Purification

- Used to optimize functionality and therefore increase value, purification can be achieved in a series of ways including chromatographic approaches, precipitation, freeze drying and crystallization.

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Scale up

- Process design – allow for differences in scaling; mixing, aeration, heat transfer as they do not scale in a linear manner. Larger fermenters can have mixing dead zones while cooling systems become more important at scale.
- Mass and Heat transfer – consider oxygen transfer and CO_2 removal rates.
- Bioreactor design – select appropriate type (stirred, air lift) and its ability to scale, can help with flow dynamics.
- Microbial considerations – nutrient distribution, strain performance at increasing volume and strict SOP for CIP and sterilization.

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Applied Biotechnology

- Genetic engineering, metabolic engineering, and synthetic biology are used to design better microbes for specific products.
- Enzyme optimization and metabolic pathway modifications improve yields
- Improved Strain Development – genetic engineering, Metabolic Engineering
- Industrial Enzyme Production – amylases, proteases.
- Microbial fermentation produces biodegradable plastics like polyhydroxyalkanoates (PHA) and polylactic acid (PLA).
- Flavor and Additives: Production of food-grade flavor compounds and additives through microbial fermentation. Example: Biotechnological production of citric acid using Aspergillus niger

Safety in fermentation

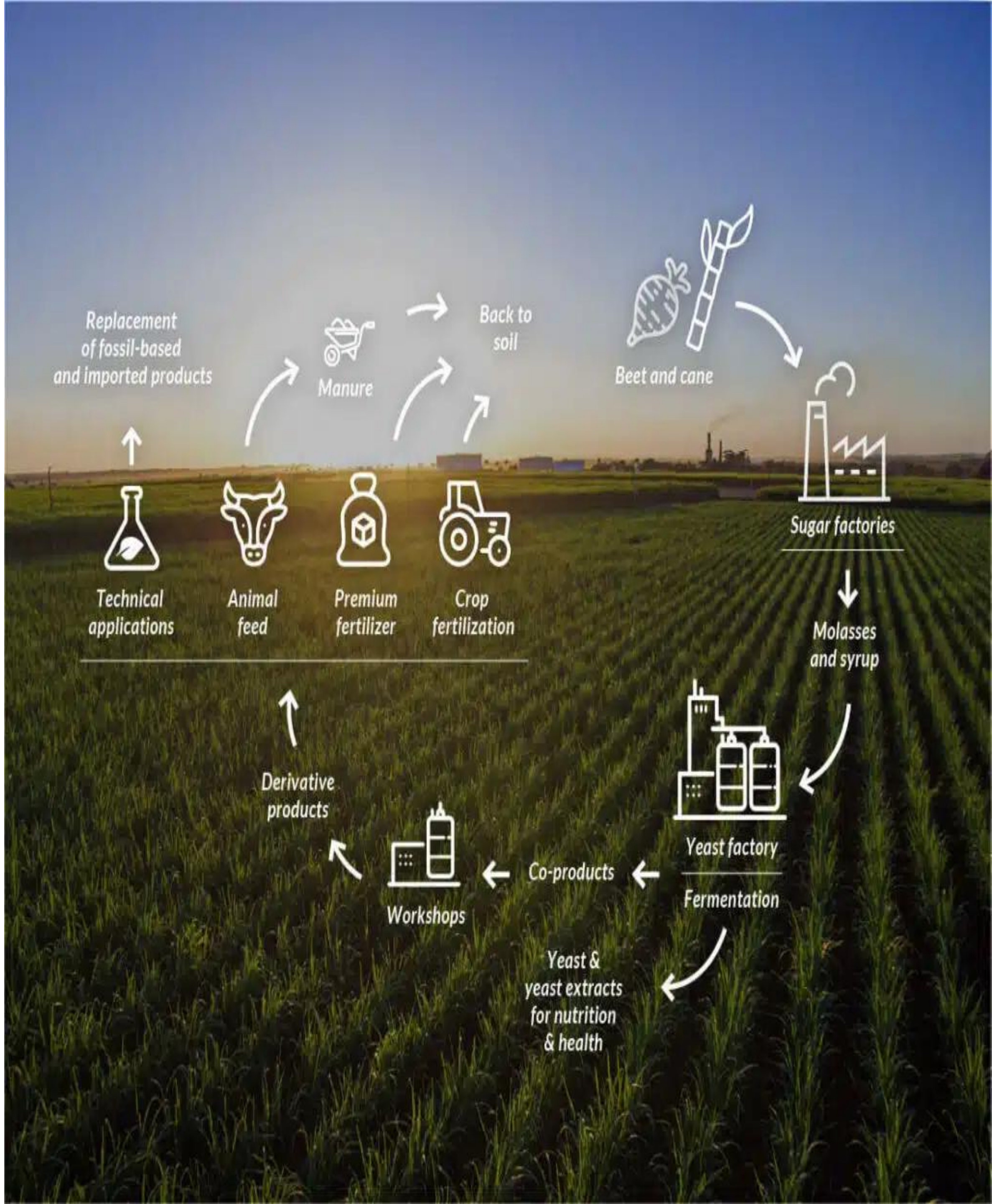
1. Personal Safety
    1. Use of containment measures (Biosafety cabinet)
    2. Sterilization procedures – effective CIP
    3. Active monitoring – build up of hazardous gases.
    4. Appropriate PPE.
    5. Sufficient training

2. Environmental Safety
    1. Containment of GMO's if in use.
    2. Waste management
    3. Emissions control.

3. Product Safety
    1. Quality control – testing for possible contaminants.
    2. Assurance of sterile conditions.
    3. Regulatory compliance – GMP.

Sustainability in fermentation

- Sustainable Feedstocks
- Energy Efficiency
- Water Management
- Waste Reduction and Management
- Carbon Footprint Reduction
- Use of Biodegradable Products
- Process Optimization and Green Technology
- Regulatory and Social Responsibility



Thank you

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Optimised fermentation process

Session 3:

Safety and risk assessment of optimised fermentation process

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Agenda

1. Key concepts in fermentation
2. Introduction to process efficiency
3. Regulatory considerations in fermentation
4. Framework for process optimization and sustainability

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1. Key concepts in fermentation

Definition: Controlled use of microorganisms to produce sustainable and nutritious food or food ingredients.

Goal: Address sustainability, affordability, and safety while minimizing environmental impact.

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Key concepts in fermentation

1. Selection strains
2. Fermentation substrates
3. Types of fermentation processes
4. Supply chain in fermentation
5. Contamination risks

1. Strains selection

Microbial Strains

Microbial strains are specific types of microorganisms used in fermentation, influencing the quality and characteristics of the final product.

Types of Microbial Strains

Fermentation employs bacteria, yeast, or fungi, such as *Lactobacillus* for lactic acid fermentation and *Saccharomyces cerevisiae* for ethanol production.

Selection Criteria for Microbial Strains

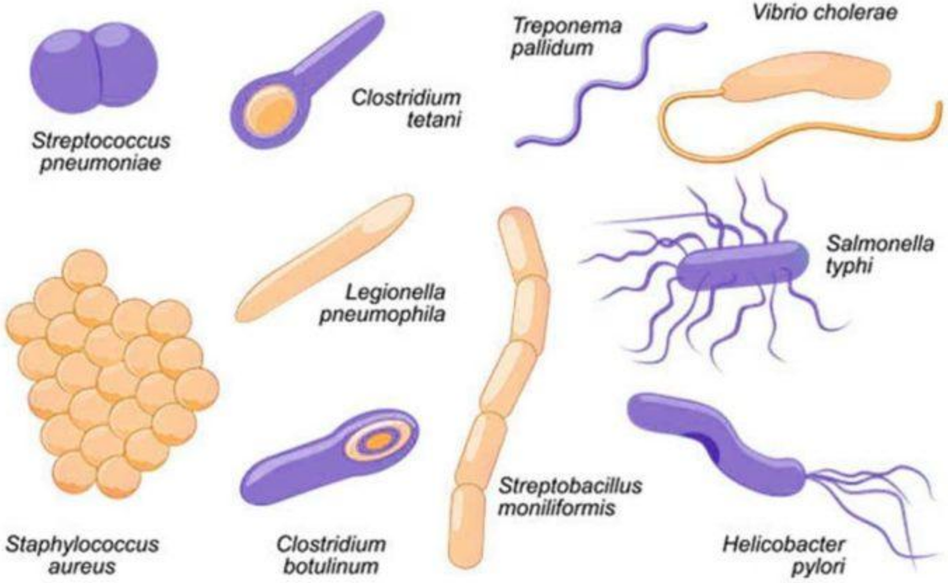
Strains are chosen for their efficiency, tolerance to environmental factors, and high production yields.

Role in Fermentation

Microbial strains transform substrates like sugars into valuable products such as ethanol, organic acids, or bioactive compounds.

Regulatory Limits

The use of microbial strains is governed by EFSA or FDA guidelines to ensure safety and compliance.



2. Fermentation substrates

Importance

The substrate (e.g., sugar, fruit pulp, or agricultural by-products) feeds the microorganisms.

Safety risks

Potential contaminants, such as pesticides, heavy metals, or mycotoxins
Allergenic raw materials that could transfer risks to the final product.

Control measures

Pre-screening and pre-treatments of the substrates for purity and safety.
Using sustainable and traceable supply chains for raw materials.

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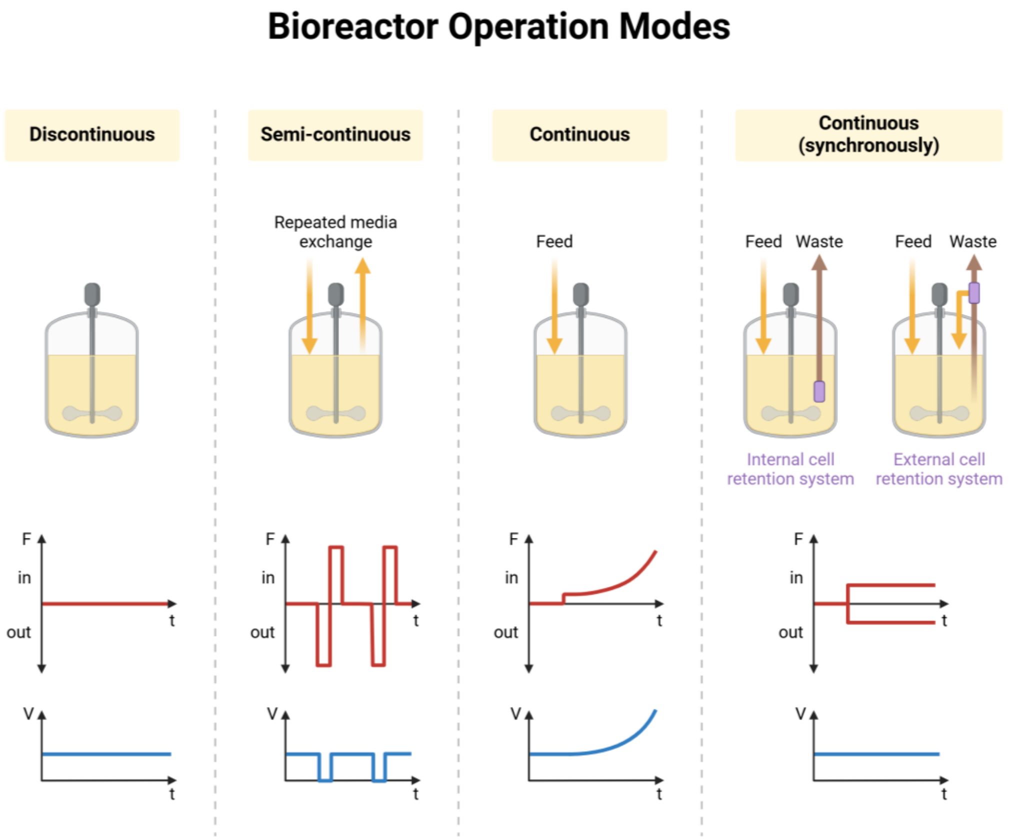
3. Types of fermentation processes

Batch fermentation: safer and easier to control contamination risks (a discontinue process)
Feed-batch fermentation: a semi-continuous process where nutrients are added during fermentation, optimizing growth and yield.
Continuous fermentation: higher efficiency but greater contamination risk.

Submerse fermentation: (probiotic, etc, in liquid media)
Solid-state fermentation: minimal water use but requires strict contamination control.

Risk Factors
Suboptimal conditions (e.g., pH, temperature) that allow contamination or toxin formation.
Open-system processes prone to external contamination.

Control Measures
Real-time monitoring of key parameters (pH, temperature, oxygen).
Use of automated and closed systems to limit external risks.



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4. Supply chain in fermentation

Risk factors

- Improper storage leading to microbial or chemical degradation
- gaps in documentation affecting traceability during recalls

Control measures

- traceability systems for all materials
- supplier audits and compliance with international safety standards

Ensuring traceability of raw materials, microbial strains, and process conditions.

Managing storage and transportation to prevent contamination.

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5. Contamination risks

Sources

Raw materials, environmental exposure, equipment, or operator errors.
Formation of harmful by-products (e.g., biogenic amines, off-flavors).

Impact

Health risks, regulatory non-compliance, or product recalls.

Mitigation

Implementation of Hazard Analysis and Critical Control Points (HACCP).
Cleaning and sterilization protocols for equipment.

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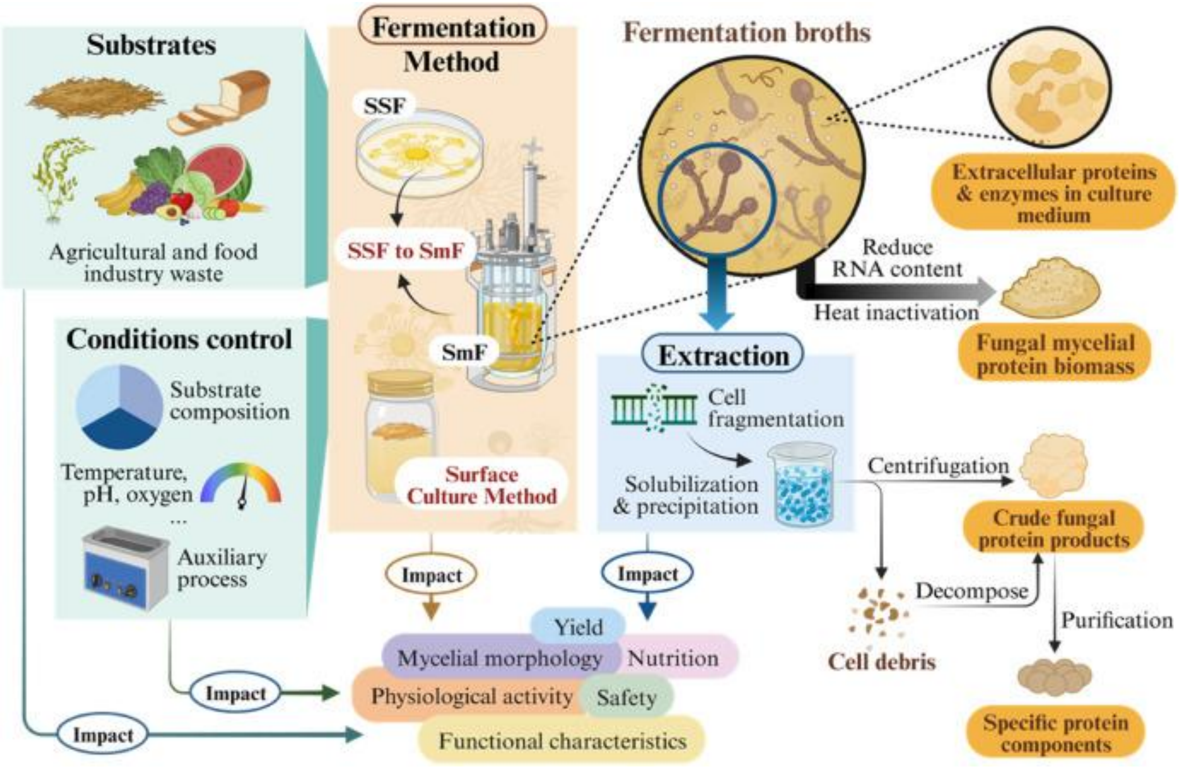
2. Introduction to process efficiency

Process efficiency refers to the ability to maximize the desired output while minimizing the use of resources (e.g., energy, raw materials, water) and reducing waste during the fermentation process.

It involves optimizing conditions to achieve high yields, minimize time, and ensure sustainable practices in the production of fermented food ingredients.



Source: **https://doi.org/10.1016/j.tifs.2023.104178**

Key aspects of process efficiency – Resource optimization

Raw material utilization

Efficient use of fermentation substrates (e.g., sugars, starches, or agricultural by-products) to ensure minimal waste and maximum conversion into the desired product.

Water and energy management

Reducing energy consumption and water usage during fermentation by using technologies like energy recovery systems, temperature control, and water recycling.

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Key aspects of process efficiency – Time efficiency

Fermentation rate

Optimizing fermentation time by controlling variables such as temperature, pH, and microbial strain activity to ensure faster processing times without compromising product quality.

Continuous vs. batch fermentation

Selecting the appropriate fermentation system (batch or continuous) based on desired production rates, product consistency, and operational costs.

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Key aspects of process efficiency – Microbial strain optimization

The selection of efficient and robust microbial strains that can tolerate stress (e.g., high ethanol, acidity) while maintaining high productivity levels. Strain optimization helps reduce process time and increase yield.

Genetic Engineering

In some cases, using genetically modified organisms to enhance microbial productivity and strain efficiency, though this requires careful regulatory compliance.

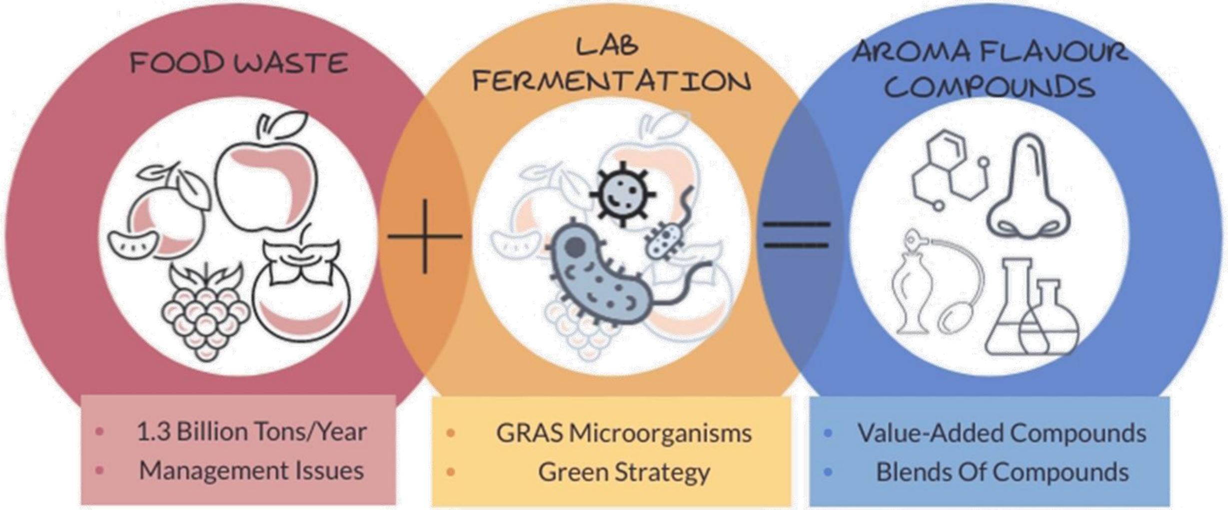
Key aspects of process efficiency – Waste minimization

By-product management

Efficient management and utilization of by-products (e.g., fermentation residuals, spent grains, or biomass) to minimize waste and possibly recycle them into other valuable products (e.g., animal feed, biofuels, or fertilizers).

Circular economy

A circular approach within fermentation processes aims to close the loop by reusing and recycling materials and energy.



Importance of process efficiency

Cost reduction

By minimizing raw material usage, reducing fermentation time, and optimizing energy consumption, companies can significantly reduce production costs, making fermented products more affordable.

Sustainability

Efficient fermentation processes are key to reducing the environmental impact of food production. This includes minimizing the carbon footprint, reducing waste, and using renewable resources.

Scalability

Optimized processes enable scaling up production without a corresponding increase in resource usage, allowing for large-scale production that remains cost-effective and sustainable.

Challenges in achieving process efficiency

Variable raw material quality

The quality of raw materials can fluctuate, affecting the consistency and yield of the fermentation process.

Microbial contamination

Uncontrolled microbial growth can lead to suboptimal fermentation conditions and loss of product quality, making strict hygiene and sterilization protocols essential.

Technological constraints

Not all fermentation systems are designed for large-scale applications, which may limit process efficiency when transitioning from laboratory to industrial-scale production.

3. Regulatory considerations in fermentation

EU Regulatory Framework

Regulations for food safety – *General Food Law Regulation (Regulation EC No 178/2002)*, which ensures traceability, risk management, and consumer safety throughout the supply chain.

Authorization of novel foods – *Novel Food Regulation (EU 2015/2283)* – pre-market authorization to ensure safety for human consumption and adherence to ethical standards.

Microbial strains approval – regulated under the *EFSA Guidelines*.
Only strains classified as Qualified Presumption of Safety (QPS) by the European Food Safety Authority (EFSA) can be utilized without further assessment.

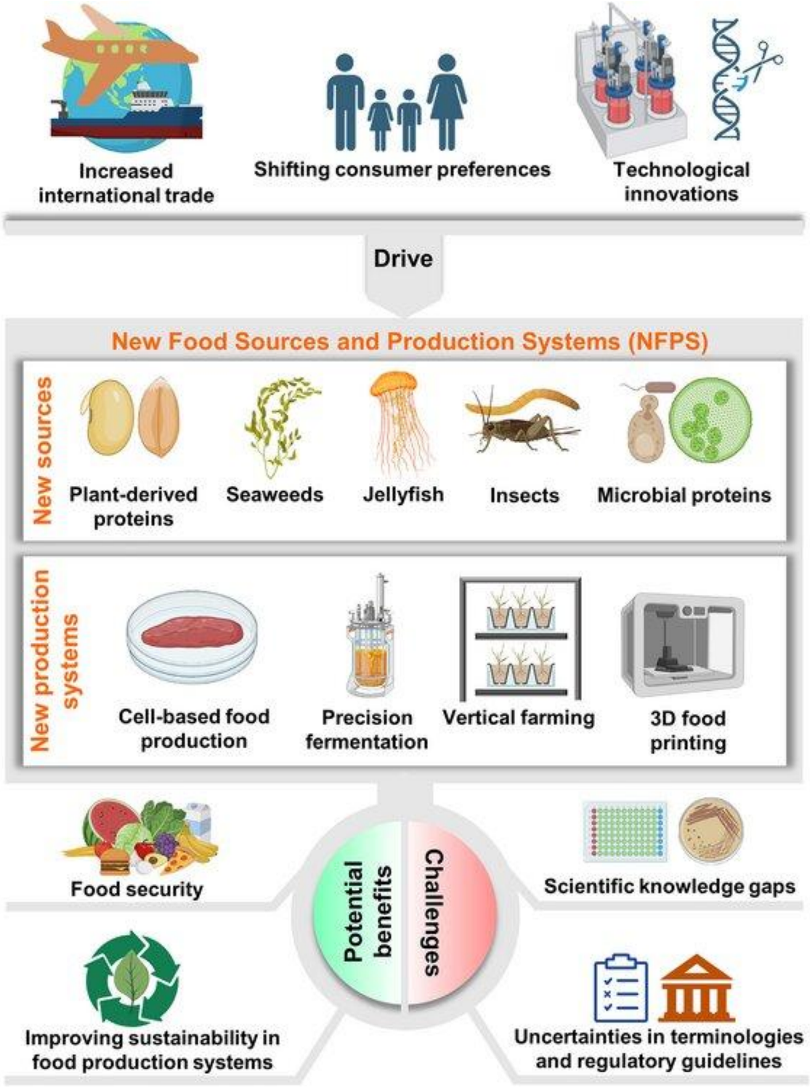
Labeling requirements – *Food Information to Consumers Regulation (EU No 1169/2011)* – proper labeling of ingredients, nutritional value, allergens, and health claims, ensuring transparency for consumers.

EU Regulatory Framework

Hygiene and Good Manufacturing Practices (GMPs) – The *Hygiene of Foodstuffs Regulation* (*EC No 852/2004*) mandates that fermentation facilities follow GMPs and Hazard Analysis and Critical Control Points (HACCP) principles to minimize contamination risks.

Use of Additives in Fermentation – *Regulation* (*EC No 1333/2008*) on food additives.

Environmental Impact Regulations – *Regulation (EU) No 995/2010*.



Source: https://doi.org/10.1111/1541-4337.13341

4. Framework for process optimization and sustainability

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Adoption of sustainable practices

- reducing waste, utilizing renewable resources, and improving energy efficiency

Integration of Advanced Technologies

- automation, artificial intelligence (AI), and Internet of Things (IoT) devices can monitor and control critical parameters like temperature, pH, and oxygen levels in real time

Use of Life Cycle Assessment (LCA)

- allows manufacturers to evaluate the environmental footprint of their processes

Improvement of microbial strain performance

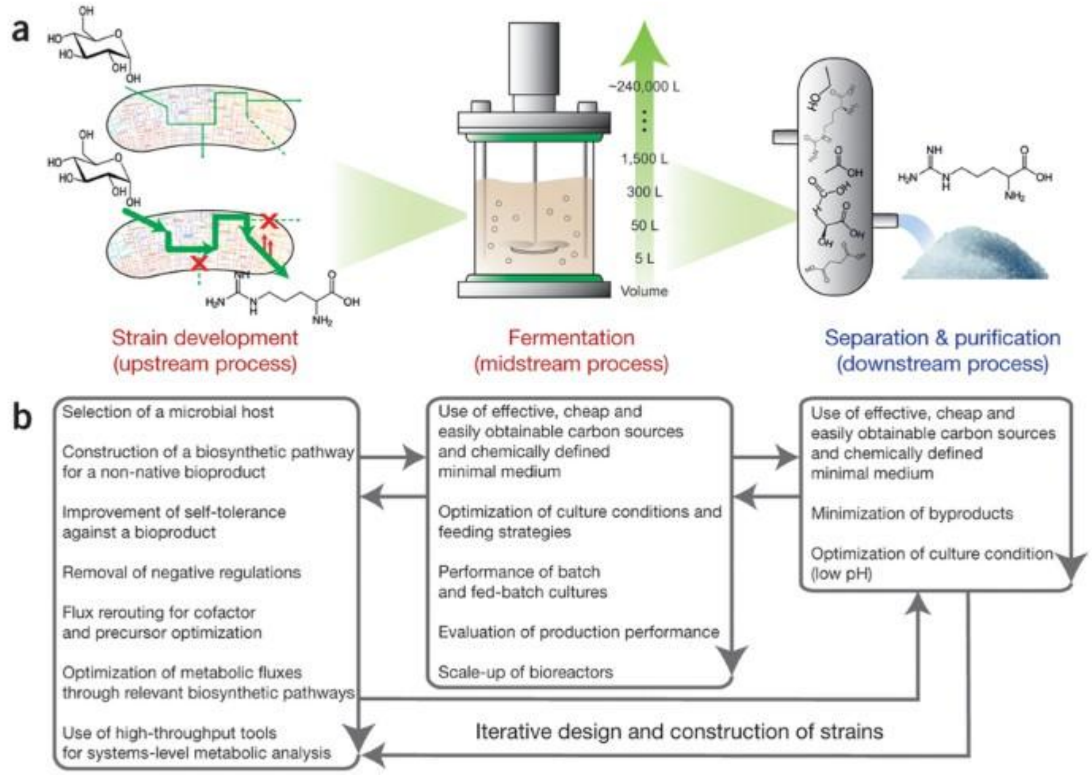
- strain optimization through genetic engineering or adaptive evolution can further enhance productivity and sustainability

Energy optimization

- employing energy-efficient equipment and renewable energy sources can significantly reduce carbon emissions and operational costs

Water recycling and management

- implementing water recycling systems ensures minimal freshwater use, reducing the environmental burden and operating expenses



Source: https://doi.org/10.1038/nbt.3365

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Valorization of by-products

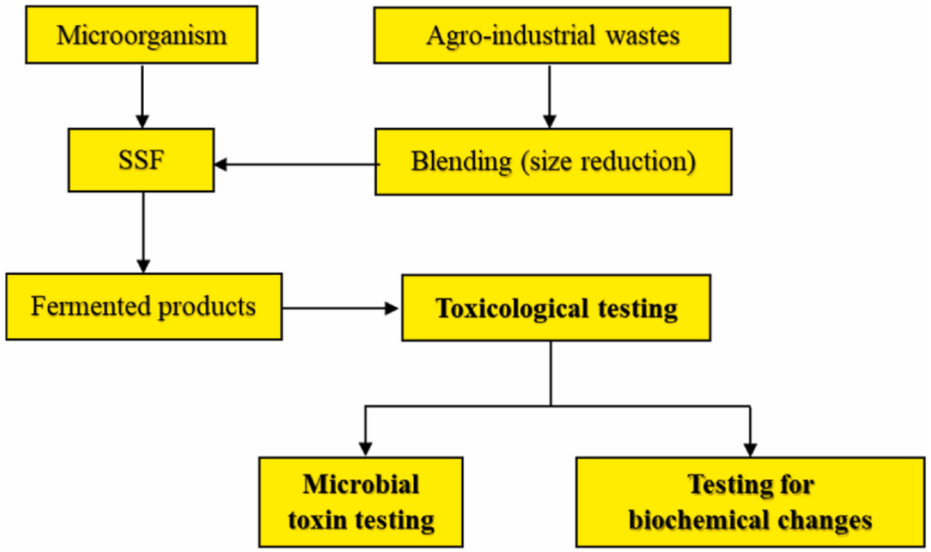
- upcycled into valuable products like animal feed, biofuels, or bioactive compounds

Regulatory compliance and certifications

- compliance with local and international sustainability standards and certifications

Continuous improvement through data-driven insights

- continuous improvement methodologies such as Lean or Six Sigma can then be applied to streamline operations while maintaining product quality



Source: https://doi.org/10.1016/j.heliyon.2023.e14814

Assessment questions

Practicality and scalability
How can advanced fermentation technologies (e.g., batch, feed-batch, continuous) and automation improve scalability and maintain efficiency across various applications?

Regulatory and logistical barriers
What are the key regulatory and logistical challenges in implementing optimized fermentation processes, and how can they be overcome to ensure safety and compliance?

Consumer trends and expectations
How can optimized fermentation align with consumer trends for sustainability and natural products while addressing concerns about safety and cost?

Environmental impact and circular economy
How does optimized fermentation contribute to reducing resource use and emissions while promoting circular economy principles in various industries?

Cost considerations
What are the cost advantages of optimized fermentation compared to traditional methods, and how can manufacturers ensure economic feasibility and ROI?

Technical and process efficiency
How do advancements in microbial engineering, real-time monitoring, and process automation enhance the efficiency and consistency of optimized fermentation processes?

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Multiple choice quiz

1. What is the main purpose of fermentation in food production?
a) To produce alcohol for beverages
b) To enhance flavor, preserve food, and create useful by-products
c) To eliminate microorganisms from food
d) To increase the temperature of the food

2. Which of the following are examples of products made using fermentation?
a) Bread
b) Yogurt
c) Vinegar
d) Cheese

3. What is a bioreactor used for in fermentation?
a) Mixing chemicals in a factory
b) Growing and controlling microorganisms for product production
c) Filtering water in industrial processes
d) Cooking food at high temperatures

4. Which microorganisms are commonly used in fermentation?
a) Bacteria
b) Yeast
c) Fungi
d) Algae

5. What are the key advantages of fermentation compared to chemical processes?
a) It requires less energy and uses natural processes.
b) It eliminates the need for microorganisms.
c) It creates synthetic chemicals faster.
d) It uses renewable and sustainable resources.

6. What role does temperature play in fermentation?
a) It has no impact.
b) It affects the speed and efficiency of microbial activity.
c) It makes the fermentation process unnecessary.
d) It stops microorganisms from growing.

7. Why is fermentation considered environmentally friendly?
a) It eliminates the need for packaging materials.
b) It uses renewable resources like agricultural waste.
c) It reduces reliance on synthetic chemical production.
d) It produces no by-products.

Thank you

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Optimized Fermentation

Session 4:

Existing optimized fermentation products: Pros and Cons

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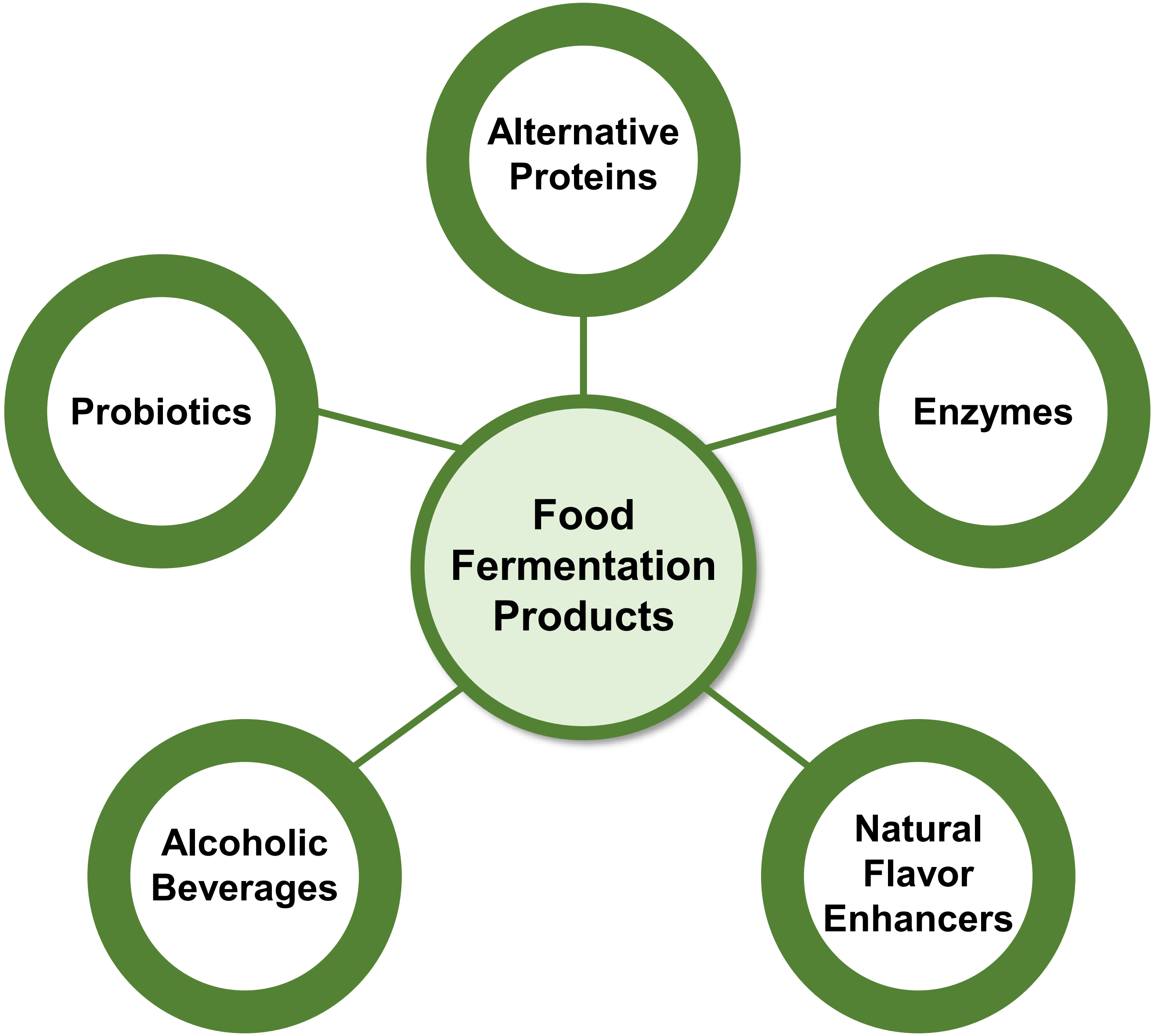
Agenda

1. Optimized Food Fermentation Products
2. Real-World Examples of Optimized Fermentation Products
3. Advantages
4. Limitations
5. Future Trends of Food Fermentation

1. Optimized Food Fermentation Products

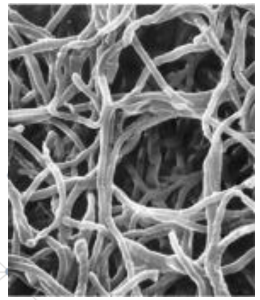


2. Real-World Examples of Optimized Fermentation Products

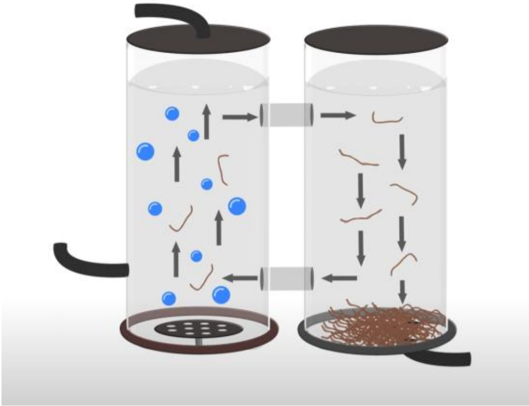
2.1. Mycoprotein-Based Products

Quorn:

- ✓ Alternative protein produced from *Fusarium venenatum;*
- ✓ Uses fungal biomass grown via fermentation on sugar-based substrates;
- ✓ Used as ingredient for alternative meat-free food products.



Fusarium venenatum



Fermentation

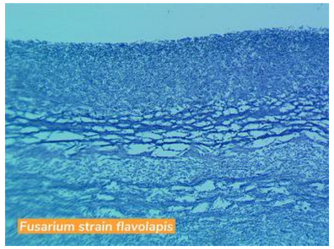
Mycoprotein

https://www.quorn.co.uk/

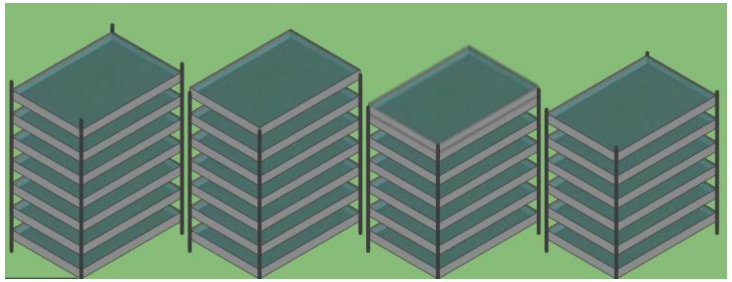
2.1. Mycoprotein-Based Products

Nature's Fynd

- ✓ Alternative protein produced from *Fusarium strain flavolapis;*
- ✓ The substrate used is often agricultural by-products;
- ✓ Developed for inclusion as an ingredient for food products such as meat, dairy, and flour alternatives.



Fusarium strain flavolapis



Fermentation

Mycoprotein

https://www.naturesfynd.com/

2.2. Seaweed or Algae-Based Products

ALGAMA

Algamafoods

- ✓ Use microalgae, such as Chlorella and Spirulina, to create sustainable proteins for use in beverages and snacks.
- ✓ Algama has been recognized with awards like the "Tech for Future 2024" prize for its innovative contributions to sustainable food production.

https://algamafoods.com/

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2.2. Seaweed or Algae-Based Products

Color & Comfort

DIC Corporation

- ✓ DIC produces food-grade natural pigments, particularly from microalgae, which are used as colorants in food and beverages.
- ✓ **Phycocyanin:** A natural blue pigment extracted from Spirulina, widely used in confectionery, beverages, and as a clean-label alternative to synthetic dyes.
- ✓ **Lutein and Astaxanthin:** Nutritional carotenoids derived from microalgae, used in dietary supplements and functional foods for their antioxidant properties.

https://www.dic-global.com/en/

2.3. Alternative Oils

C16 Biosciences

- ✓ A sustainable alternative to palm oil using optimized fermentation processes. The company leverages yeast strains to produce a palm oil substitute with a similar fatty acid profile, making it functionally equivalent to palm oil in various industries, including food and personal care.
- ✓ Their product, Palmless™, is produced by fermenting non-GMO oleaginous yeast, which can generate oils rich in palmitic acid—a key component of palm oil.

C16 Biosciences

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3. Advantages

- Increased yield and efficiency
- Cost effectiveness
- Consistency and quality control
- Environmental benefits
- Customization for novel products

4. Limitations

- High initial investment
- Complexity in implementation
- Risk of contamination
- Dependence on precise parameters
- Potential for reduced genetic diversity
- Regulatory challenges

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5. Future Trends of Food Fermentation

- Precision fermentation
- Alternative substrates
- Expanded applications
- Sustainability and circular economy
- Advances in microbial engineering
- Clean label products
- Affordable alternatives
- Regional and cultural integration
- Regulatory and consumer acceptance

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Questions

1. What is one of the main benefits of optimized fermentation in the food industry?

A) Reducing production time for traditional food products

B) Reducing environmental impact by using alternative substrates

C) Increasing the price of fermented food products

D) Increasing the reliance on animal-derived ingredientes

2. Which of the following companies produces animal-free dairy products using optimized fermentation?

A) Geltor

B) Nature's Fynd

C) Algamafoods

D) Meati Foods

Questions

3. Which of the following alternative substrates are being used in optimized fermentation processes?

A) Animal fat and muscle tissue
B) Plant sugars, agricultural waste, and CO_2
C) Raw animal byproducts
D) Only chemical compounds derived from synthetic sources

4. What is one of the primary advantages of optimized fermentation for food production?

A) It always produces products that are less expensive than traditional methods
B) It allows for the production of high-quality, sustainable ingredients without relying on animals
C) It is faster but less efficient than traditional fermentation
D) It increases the dependence on fossil fuels for production

Assessment
Multiple choice quiz

Safety and risk assessment of optimized fermentation process

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