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A Review Article On Yeast And Bacteria In Sustainable Biofuel Production

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ABSTRACT:

Nowadays, technological advancement is increasing rapidly, and the global demand for energy in the automobile sector is rising significantly. People should reduce their dependence on fossil fuels and start using natural or biological sources as sustainable alternatives. Microorganisms like yeast and bacteria play a vital role in the production of biofuels such as bioethanol, biodiesel, biogas, and biodegradation. These microorganisms produce diverse enzymes that can convert complex organic materials into simple molecules, which are rich in energy and can be used to produce biofuels.

INTRODUCTION:

Yeast and bacteria are the most preferable microorganisms because of their unique characteristics, such as rapid growth, easy cultivation, and high metabolic activity. These microorganisms play a vital role in the sustainable production of different types of biofuels.

Organisms used in biofuels production:

- **Yeast (saccharomyces cerevisiae)** and **Bacteria (Zymomonasmobilis)**from sugarcane and corn cellulose are used to produce **bioethanol.**
- **Clostridium species** from agricultural waste produce **biobutanol.**
- **Bacteria (Rhodococcus species)** from waste oils and lipids produce **biodiesel.**
- **Clostridium species** from wastewater and organic acids produce **biohydrogen**
- **Methanogenic bacteria** from organic waste produce **biogas.**

Fossil fuels like coal, petroleum, and natural gas are very precious because they are non-renewable resources that cannot be replenished once exhausted. Continuous use of these fuels leads to environmental pollution and global warming, which negatively affects sustainable living.

. Role of Yeast in Biofuel Production

Yeasts are among the most widely used microorganisms in industrial biofuel production, particularly for **bioethanol**. Their strong fermentative abilities, tolerance to high ethanol concentrations, and ease of genetic manipulation make them ideal biocatalysts.

Key Roles

1.1 Ethanol Production from Sugars

- *Saccharomyces cerevisiae* is the primary organism used for first-generation (sugar- and starch-based) ethanol.
- Converts glucose, sucrose, and maltose efficiently into ethanol through glycolysis and alcoholic fermentation.
- Tolerates up to 12–15% ethanol — higher than most microbes.

1.2 Lignocellulosic Bioethanol

- Non-*Saccharomyces* yeasts like *Pichia stipitis*, *Candida shehatae*, and *Kluyveromyces marxianus* ferment **pentose sugars (xylose, arabinose)** found in agricultural waste.
- Plays a major role in second-generation biofuels.

1.3 Lipid-Producing Yeasts for Biodiesel

- Oleaginous yeasts (e.g., *Yarrowia lipolytica*, *Cryptococcus curvatus*) accumulate **20–70% lipids**, which can be converted into biodiesel.
- They utilize low-cost substrates such as waste glycerol and food-processing waste.

1.4 Thermotolerant and Stress-Resistant Yeasts

- *K. marxianus* grows at 45–50°C, reducing cooling costs in fermentation.
- Engineered strains can tolerate high osmotic pressure, inhibitors (furfural, HMF), and acidic conditions in lignocellulosic hydrolysates.

1.5 Recombinant and Synthetic Biology Approaches

- CRISPR-based engineering allows yeasts to co-ferment hexoses + pentoses.
- Engineered *S. cerevisiae* strains produce isobutanol, butanol, and bio-jet fuels.

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2. Role of Bacteria in Biofuel Production

Bacteria offer high metabolic versatility and can produce diverse biofuels such as **bioethanol, biobutanol, biogas, hydrogen, and biodiesel**.

Key Roles

2.1 Bacterial Ethanol Producers

- *Zymomonas mobilis* uses the Entner–Doudoroff pathway, producing ethanol with high yields and low biomass formation.
- Requires less aeration and shows high sugar uptake rates.

2.2 Butanol and Acetone–Butanol–Ethanol (ABE) Fermentation

- *Clostridium acetobutylicum* and *C. beijerinckii* ferment sugars into butanol, a superior biofuel with higher energy density.
- Can convert a wide range of substrates including molasses and lignocellulosic hydrolysates.

2.3 Biodiesel from Lipid-Producing Bacteria

- *Rhodococcus opacus* and *Bacillus* spp. accumulate intracellular lipids (triacylglycerols) suitable for biodiesel conversion.
- Can utilize industrial waste streams and crude glycerol.

2.4 Hydrogen Gas Production

- Photosynthetic bacteria (*Rhodobacter sphaeroides*) and anaerobic bacteria (*Clostridium butyricum*) generate H_2 through fermentation and photobiological processes.

2.5 Biogas Production

- **Methanogenic archaea** (though not bacteria, they operate in bacterial consortia) convert organic waste into methane via anaerobic digestion.
- Synergistic action of hydrolytic, acidogenic, and acetogenic bacteria enables efficient CH_4 production.

2.6 Waste-to-Fuel Conversion

- Lignocellulose-degrading bacteria (*Cellulomonas*, *Bacillus*, *Clostridium*) break down cellulose and hemicellulose into fermentable sugars.
- Excellent for agro-waste and food waste valorization.

3. Metabolic Pathways in Microbial Biofuel Production

Microorganisms use several biochemical pathways to convert biomass into biofuels. These include:

3.1 Glycolysis (EMP Pathway)

- Converts glucose into pyruvate.
- Produces ATP and NADH.
- In yeasts, pyruvate is converted to ethanol via **pyruvate decarboxylase** and **alcohol dehydrogenase**.

3.2 Entner–Doudoroff Pathway (ED Pathway)

- Used by *Z. mobilis*.
- More efficient sugar uptake, lower ATP yield → higher ethanol productivity.
- Produces ethanol with fewer by-products.

3.3 Pentose Phosphate Pathway (PPP)

- Essential in pentose-fermenting yeasts like *P. stipitis*.
- Converts xylose → xylulose → enters central carbon metabolism.
- Important in lignocellulosic ethanol production.

3.4 ABE Fermentation Pathways

Used in *Clostridium* spp.

Acidogenesis Stage

- Sugars → acetic acid, butyric acid, CO_2, H_2
- Generates ATP but lowers pH.

Solventogenesis Stage

- Acids → acetone, butanol, ethanol
- pH increase triggers solvent formation.

3.5 Lipid Biosynthesis Pathways

In oleaginous yeasts and bacteria:

- Excess carbon + nitrogen limitation → acetyl-CoA accumulated
- Channelled into fatty acid biosynthesis
- Produces triacylglycerols (TAGs) → biodiesel feedstock

3.6 Photosynthetic and Photobiological Pathways

Used by certain bacteria for H_2 production:

- Light energy → water splitting
- Ferredoxin-mediated hydrogenase activity → H_2 release

3.7 Anaerobic Digestion Pathway

Four steps:

1. **Hydrolysis** – polymers → monomers
2. **Acidogenesis** – monomers → VFAs
3. **Acetogenesis** – VFAs → acetate + H_2
4. **Methanogenesis** – acetate/H_2 → methane

CONCLUSION:

Everyone has a responsibility to protect our plant and preserve
Natural resources for future generations. By using natural and biological processes, we can reduce our dependence on fossil fuels. This approach not only helps in preventing pollution but also protects the environment by managing agricultural and industrial wastes. These biofuels are eco-friendly and do not cause any damage to the environment. Therefore, the utilization of yeast and bacterial species in biofuel production represents a great step towards achieving global energy sustainability and environmental protection.

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