BIOTECHNOLOGY



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April 2024

UNIT 1

BIOTECHNOLOGY

What is Biotechnology?

- It is comprised of "bio" and "technology"
  - *Bio* refers to life or living organisms
  - *Technology* refers to the application of scientific knowledge for practical purposes.
- It is the use of microorganisms to make things that people want, often involving industrial production.
- Biotechnology is based on microbiology.
  - **Microbiology** is the study of micro-organisms and their effect on humans.
  - With the arrival of genetic engineering, microorganisms are becoming more useful.
    - ✓ Not all types of microorganism are used in biotechnology.

The Significance of Biotechnology

- It has always been extremely important.
- It has enormous significance in helping people to improve and control their lives.
- It involves ways of making and preserving foods and making alcoholic drinks.
  - Fermentation has been employed to produce alcoholic beverages and fermented foods.
    - ✓ Yeast is used to make injera, tej and tella.
    - ✓ Bacteria are used in the manufacture of yoghurt and cheese.
- Modern biotechnology applications encompass several key areas:
  - manipulating the genetic material of organisms to introduce desirable traits.
  - the production of new medicines, vaccines, antibodies, and recombinant proteins.
  - the development of new energy sources through the production of biofuels.

The Traditional Uses of Biotechnology

a) Preparing bread

- Yeast plays a vital role in the process of making bread through fermentation.
- When yeast cells break down sugar in the absence of oxygen, they produce ethanol and CO_2.
  - The CO_2 forms bubbles in the dough, causing it to rise.
  - The fermentation process also imparts flavor and aroma to the bread.
- In Ethiopia, yeast (ershoo) has been used to make injera.

Steps in making injera

1. Grind teff or barley and mix it with water.
2. Leave the dough at room temp for 2 days.
3. Yeast produces CO_2 in dough, causing it to rise slightly.
4. Cook dough on hot surface.
5. Gas bubbles expand and create porous texture.
6. High heat kills yeast during cooking, halting fermentation.

b) Preparing Alcoholic Drinks

- Alcoholic drinks are produced through fermentation process.
- Yeast breaks down sugars to form ethanol and carbon dioxide.
    - Yeast must respire anaerobically for alcohol production.
- High alcohol concentrations can be toxic to yeast.
    - The alcohol content in fermented beverages is limited.
- **Beer** is typically made from grains like barley.
    - The grains are malted, mashed, boiled, and fermented with yeast.
    - The result is a beverage (beer) with varying alcohol content (4-6%).
- **Tej** is one of the oldest known alcoholic drinks in Ethiopia.
    - It is made from honey, water, and gesho leaves or sticks.
        - ✓ Gesho (Abyssinian hop) imparts a bitter flavor.
        - ✓ Wild yeasts on the gesho plant initiate fermentation.
    - Its alcohol content ranges from 6 to 11%.
- **Wine** is made predominantly from grapes.
    - It can also be made from other fruits or vegetables.
    - Yeast is added to grape juice along with water to initiate fermentation.
    - The wine is then aged to mature flavors.
    - Commercially sold wine typically has an alcohol content of up to 14%.

c) Preparing yoghurt

- Yoghurt has been a staple diet in Ethiopia.
- It involves fermenting whole milk with bacteria.
    - Lactic fermentation causes the milk to solidify into yoghurt.
- The lactose in the milk is broken down by bacteria and lactic acid is produced.
    - The action of *Lactobacillus bulgaricus* and *Streptococcus thermophilus* is important.
    - The lactic acid gives yoghurt its characteristic tangy flavor.

The Stages

1. Add starter culture to warm milk.
    - Use a small amount of previously made yoghurt.
2. Maintain warmth for bacterial fermentation.
3. The bacteria convert lactose to lactic acid and the milk is solidified.
4. Lactic acid gives yoghurt its tangy taste.
5. Yoghurt forms smooth, thick texture.
6. The lactic acid bacteria prevent spoilage, extending shelf life.

- Flavorings, spices, and fruit can be added to yoghurt.
- If stored properly, yoghurt can last almost three weeks.

d) Preparing cheese

- Cheese is a dairy product and forms by coagulation of casein (milk protein).
    - Over 900 types of cheese exist.
- A required step in cheese making is separating the milk into solid curds and liquid whey.
    - Curds are formed by the action of bacteria on the milk.
- Most cheeses are made with starter bacteria from the *Lactococcus*, *Lactobacillus*, or *Streptococcus* genera.

Stages in traditional Ethiopian cheese making

1. Fresh milk is first turned into yoghurt through fermentation.
2. The yoghurt undergoes continuous agitation to separate the butter.
3. The remaining portion after butter extraction is boiled to produce cheese.

Checkpoint 1

1. What is biotechnology?
    A. It is the use of modern technology in biology laboratories.
    B. It is the study of heredity and variation in microorganisms.
    C. It is the study of genetic engineering principles and processes
    D. It is the use of microorganisms to make things that people want.
2. How does biotechnology contribute to people's lives?
    A. By reducing the use of vaccines and medicines
    B. By restricting recent technological advancements
    C. By helping people improve and control their lives
    D. By increasing dependence on traditional methods

3. Which field is the foundation of biotechnology?
    A. Microbiology
    B. Chemistry
    C. Genetics
    D. Technology
4. How has genetic engineering impacted the utilization of microorganisms?
    A. Reduced their utility
    B. Made them less diverse
    C. Increased their usefulness
    D. Restricted their application
5. Which of the following is **NOT** a modern application of biotechnology?
    A. Producing new medicines and vaccines
    B. Modifying DNA to introduce desirable traits
    C. Manufacturing alcoholic drinks like tej and tella
    D. Developing renewable energy sources such as biofuels
6. What role does yeast play in bread making?
    A. It adds sweetness to the bread.
    B. It enhances the color of the bread crust.
    C. It provides structural support to the dough.
    D. It ferments sugar to produce carbon dioxide.
7. What is the role of yeast (ershoo) in making injera?
    A. It provides color to the injera.
    B. It gives a sour taste to the injera.
    C. It acts as a preservative for the injera.
    D. It ferments the dough to create bubbles.
8. What happens when yeast cells break down sugar in the absence of oxygen?
    A. Glucose, oxygen and ATP are produced.
    B. Ethanol and carbon dioxide are produced.
    C. Lactic acid and ethyl alcohol are produced.
    D. Acetic acid and carbon dioxide are produced.
9. How are alcoholic drinks primarily produced?
    A. Fermentation
    B. Distillation
    C. Filtration
    D. Carbonation
10. Which alcoholic beverage usually has the highest alcohol content?
    A. Tej
    B. Wine
    C. Beer
    D. Sofi malt

New Applications of Biotechnology

- Traditional biotechnologies hold significant importance worldwide.
- New applications of biotechnology (e.g. Genetic engineering) have emerged in industrial settings.
- Genetic engineering is used to change an organism and give it new characteristics which people want to see.
- A lot of new biotechnology relies on growing large numbers of microorganisms on an industrial scale in fermenters.
- Industrial fermenters usually have an oxygen supply, a stirrer, a water-cooled jacket and measuring instruments.
- There are different areas where biotechnology or genetic engineering is very important.

a) Applications of biotechnology in agriculture

- Selective breeding relies on natural genetic variation and controlled mating to improve traits over generations.
- Biotechnology allows for precise genetic modifications to introduce specific traits in a shorter timeframe.
- Biotechnology may be preferred when aiming for rapid improvements or when targeting traits that are difficult to achieve through selective breeding alone.
    - Introducing new characteristics rapidly through genetic engineering is possible.
- Applications of biotechnology in agriculture include:
    - Improving growth rates of plants and animals.
    - Enhancing the food value of crops.
    - Developing crop plants resistant to drought and disease.
    - Producing plants that can produce their own pesticide chemicals.
    - Creating crop plants that emit a blue light when attacked by insects.
        - ✓ It reduces the need for insecticides.

b) Applications of biotechnology in food production

- Applications of biotechnology in food processing include:
    - Production of enzymes using genetically engineered bacteria
    - Enzymes clarify beer, break down starch into glucose syrup, tenderize meat, and produce commercial baby food.

- Mycoprotein serves as a high-protein, low-fat meat substitute in vegetarian diets.
    - ✓ In addition to protein, it also contains dietary fiber, vitamins, and minerals.
    - ✓ The filamentous fungi *Fusarium venenatum* is used to produce mycoprotein.

c) Applications of biotechnology in medicine

- Production of vaccines, new medicines, proteins and hormones through genetic engineering.
    - Human blood clotting protein can be produced in milk by introducing the gene responsible for producing the protein into the genome of a mammalian host.
    - Isolating the gene for human insulin and inserting it into the genome of bacteria enables the bacteria to produce insulin.
    - Vaccines can be developed by introducing genes encoding antigens from pathogens into harmless host organisms.

d) Applications of biotechnology in energy production

- Biotechnology is promising for the development of renewable and environmentally friendly energy solutions.
- **Biogas** is a renewable energy source and depends on biotechnology.
    - Biogas is primarily composed of methane (50 – 80%), carbon dioxide (15 – 45%), water vapor (5%), hydrogen sulfide (0 – 3%), and other gases such as H_2 (0 – 1%).
    - It is made by anaerobic break down of plant matter and waste in a biogas generator.
        - ✓ Under ideal conditions, 10 kg of dry dung can produce 3 m^3 of biogas.
    - Biogas-forming bacteria belong to diverse groups including methanogens, acetogens, and hydrolytic bacteria.
        - ✓ Biogas-forming bacteria are present in the digestive systems of ruminants.
- **Ethanol** can be made from sugar cane, maize and sweet potatoes by fermentation.
    - Ethanol can be extracted from the products of fermentation by distillation.
    - It can be used in cars and other vehicles as a fuel.
    - Using ethanol as a fuel is a carbon-neutral activity.
    - It offers advantages such as efficiency, reduced toxic emissions, and the ability to be mixed with petrol to create gasohol.
    - The primary drawback of using ethanol as a fuel is substantial amount of plant material is required for its production.
- **Biodiesel** can be made from castor oil bean and jatropha.
    - It is a renewable and environmentally friendly alternative to diesel fuel.
    - Castor oil bean and jatropha are non-food crops.

Checkpoint 2

1. What term refers to the process that uses laboratory-based technologies to alter the DNA makeup of an organism?
   A. Genetic mutation
   B. DNA transcription
   C. Genetic engineering
   D. DNA recombination
2. What is the primary purpose of genetic engineering?
   A. To reduce the global dependence on biotechnological processes.
   B. To change an organism and give it new desired characteristics.
   C. To eliminate the need for industrial fermenters and microorganisms.
   D. To preserve the characteristics of organisms through DNA modification.
3. Which of the following is **NOT** typically found in industrial fermenters?
   A. Stirrer
   B. Solar panels
   C. Oxygen supply
   D. Water-cooled jacket
4. What is the primary aim of selective breeding in agriculture?
   A. To reduce the need for insecticides and pesticides.
   B. To introduce genes into organisms to modify them.
   C. To improve desirable traits in organisms over generations.
   D. To enhance the food value of crops in a short period of time.
5. What distinguishes biotechnology from selective breeding?
   A. It does not allow for precise genetic modifications, whereas selective breeding involve direct manipulation of genetic material.
   B. It typically focuses on selecting individuals with desired traits, whereas selective breeding may involve genetic engineering.
   C. It involves the manipulation of the genetic material, while selective breeding relies on natural genetic variation and controlled mating.
   D. It can not achieve desired traits in a shorter timeframe compared to selective breeding, which relies on improvements occurring over generations.
6. Which statement best describes the role of biotechnology in agriculture?
   A. It optimizes the production of various industrial products.
   B. It plays a role in the development and production of pharmaceuticals.
   C. It plays a significant role in the production of biofuels such as ethanol.
   D. It allows for rapid of crop improvements through genetic modifications.

7. What advantage does biotechnology offer in creating crop plants that produce their own pesticide chemicals?
    A. It accelerates the process of selective breeding.
    B. It improves pesticide resistance in insect pests.
    C. It increases the reliance on synthetic pesticides.
    D. It reduces the need for external chemical pesticides.
8. Which characteristic makes biotechnology preferable for rapid improvements in agriculture?
    A. Its ability to introduce specific traits in a shorter timeframe.
    B. Its slower pace compared to traditional breeding methods.
    C. It relies on natural genetic variation and controlled mating.
    D. Its ability to be propagated and disseminated on a small scale.
9. Applications of biotechnology in agriculture include all of the following **EXCEPT**
    A. improving growth rates of plants and animals
    B. extraction of metals from ores through bioleaching
    C. developing crop plants resistant to drought and disease.
    D. producing plants that can produce their own pesticide chemicals.
10. What is a potential benefit of crop plants emitting blue light when attacked by insects?
    A. Reduced need for insecticides.
    B. Improved drought resistance.
    C. Increased attraction of insects.
    D. Reliance on chemical pesticides.
11. How do enzymes contribute to food processing?
    A. They increase food spoilage.
    B. They have no role in food processing.
    C. They reduce the nutritional value of food.
    D. They break down starch into glucose syrup.
12. What role does mycoprotein play in vegetarian diets?
    A. It is produced from animal and plant sources.
    B. It is used to enhance the flavor of meat dishes.
    C. It provides dietary fiber, vitamins, and minerals.
    D. It serves as a low-protein, high-fat meat substitute.
13. Which filamentous fungus is used to produce mycoprotein?
    A. *Fusarium venenatum*
    B. *Saccharomyces cerevisiae*
    C. *Aspergillus niger*
    D. *Penicillium notatum*
14. Which of the following is an application of biotechnology in medicine?
    A. Production of new medicines through genetic engineering

B. Production of vaccines using chemical synthesis methods
C. Creation of new medicines through mechanical processes
D. Extraction of proteins and hormones from natural sources

15. How is human blood clotting protein produced in sheep's milk?
    A. By introducing the gene responsible for producing the blood clotting protein into the genome of the sheep
    B. By direct manipulation of the sheep's physical traits without affecting its genetic makeup.
    C. By introducing the soluble human blood clotting protein into the sheep's milk after production
    D. By fermenting the sheep's milk containing the human blood clotting protein with lactic acid bacteria
16. What would likely happen if the gene for human insulin is isolated and inserted into the genome of bacteria?
    A. The bacteria would become resistant to many antibiotics.
    B. The bacteria would lose their ability to reproduce sexually.
    C. The bacteria would produce insulin using the inserted gene.
    D. The bacteria would die due to the toxic effects of the new gene.
17. How are vaccines developed using biotechnology?
    A. By isolating specific antibodies from pathogens and injecting them into the body
    B. By exposing individuals to live pathogens so that they produce natural antibodies
    C. By introducing genes encoding antigens from pathogens into harmless host organisms
    D. By removing the specific antigens from pathogens to suppress an immune response.
18. Which of the following is **NOT** a component of biogas?
    A. Methane
    B. Carbon dioxide
    C. Hydrogen sulfide
    D. Carbon monoxide
19. What is the primary drawback of using ethanol as a fuel?
    A. It can not be blended with gasoline or petrol to create gasohol.
    B. It contributes to air pollution, acid rain, and global climate change.
    C. A substantial amount of plant material is required for its production
    D. Its production, extraction and burning can lead to habitat destruction
20. What is biodiesel primarily made from?
    A. Palm oil and coconut oil
    B. Castor oil bean and jatropha
    C. Lettuce and cucumbers
    D. Sunflower seeds and soybeans

Answers for the checkpoints

Checkpoint 1

1. D
2. C
3. A
4. C
5. C
6. D
7. D
8. B
9. A
10. B

Checkpoint 2

1. C
2. B
3. B
4. C
5. C
6. D
7. D
8. A
9. B
10. A
11. D
12. D
13. A
14. A
15. A
16. C
17. C
18. D
19. C
20. B