Production of Citric Acid

Introduction

- **Citric acid** is a **tricarboxylic acid ($C_6H_8O_7$)**, a weak organic acid.
- First isolated from lemon juice by **Carl Wilhelm Scheele (1784)**.
- Used widely in **food, beverage, pharmaceutical, and cosmetic industries**.
- **Microbial fermentation** is the major method of industrial production (accounts for >90% of the world's citric acid supply).

Microorganism Used

- **Aspergillus niger** (filamentous fungus) – most widely used due to high yield.
- **Yeasts** (e.g., *Candida lipolytica*, *Yarrowia lipolytica*) – can use hydrocarbons as substrate.
- Mutant strains of *A. niger* are developed for increased yield.

Raw Materials

1. **Carbon sources**:
    - Molasses, starch hydrolysates, sucrose, glucose.
    - Cheap raw materials are preferred for economic production.
2. **Nitrogen sources**:
    - Corn steep liquor, ammonium salts, peptones (low concentration – as nitrogen limitation favors citric acid production).
3. **Minerals**:
    - Trace elements required, but heavy metals like iron, zinc, and manganese must be avoided (they inhibit citric acid accumulation).
4. **Other supplements**:
    - Methanol (low concentration) is sometimes added to increase yield.

Fermentation Process

Industrial production of citric acid is done by **submerged fermentation** and **surface fermentation**.

1. Inoculum Preparation

- *A. niger* spores are grown on agar slants.
- Spores transferred to seed flasks → seed tanks → production fermenter.

2. Production Fermentation

- **Types**:
    - **Submerged fermentation (SmF)** – widely used, high productivity.
    - **Surface fermentation** – older method, used in some regions (using trays).
- **Conditions**:
    - pH: 2.0–3.5 (acidic conditions favor citric acid accumulation).
    - Temperature: 28–30°C.
    - Aeration: High (citric acid production is aerobic).
    - Duration: 5–10 days.

- Nitrogen limitation is essential (prevents biomass growth and channels metabolism toward citric acid).

3. Metabolic Pathway

- Citric acid is an intermediate of the **TCA cycle (Krebs cycle)**.
- Normally, it is converted further into isocitrate → α-ketoglutarate.
- But under specific conditions (excess sugar, nitrogen limitation, metal ion deficiency), **A. niger accumulates large amounts of citric acid and secretes it into the medium**.

Recovery and Purification of Citric Acid

1. **Filtration** – fungal mycelium separated from broth.
2. **Precipitation** – citric acid is precipitated as **calcium citrate** by adding lime ($Ca(OH)_2$).
3. **Filtration** – calcium citrate separated.
4. **Acid treatment** – calcium citrate treated with sulfuric acid → citric acid + calcium sulfate (gypsum).
5. **Purification** – activated charcoal is used to remove color and impurities.
6. **Crystallization** – citric acid crystals obtained.

Flowchart – Production of Citric Acid

👉 You can draw this simple flowchart in exams:

A. niger spores → Inoculum preparation → Fermenter (submerged, aerobic)
| (Sugar solution + low nitrogen + aeration, pH 2-3)
↓
Citric acid accumulated in the broth
↓
Filtration → Precipitation with $Ca(OH)_2$ (Ca citrate formed)
↓
Treatment with H_2SO_4 → Citric acid + $CaSO_4$ (byproduct)
↓
Purification → Crystallization → Citric Acid (final product)

Applications of Citric Acid

1. **Food Industry**
   - As flavoring agent (soft drinks, candies, jams, jellies).
   - As preservative (E330).
   - Acidulant (adds sour taste, controls pH).
2. **Pharmaceutical Industry**
   - As an anticoagulant (prevents blood clotting by binding calcium).
   - In effervescent tablets and syrups.
   - Enhances absorption of minerals (iron, calcium).
3. **Industrial Uses**
   - In detergents (binds hardness ions like Ca^{2+}, Mg^{2+}).
   - Used in cosmetics (skin-care creams, shampoos).
   - As a plasticizer in biodegradable plastics.
4. **Biotechnology**
   - Used in buffer preparation for molecular biology experiments.

Advantages of Microbial Production

- Uses cheap raw materials.
- Environmentally friendly.
- High yield and easy downstream processing.

Conclusion

- Citric acid is a **high-value product** of industrial microbiology.
- **Aspergillus niger fermentation** is the primary method for its production.
- With its wide applications in **food, medicine, and industry**, citric acid remains one of the most successful products of **industrial biotechnology**.