Department of Post Harvest Process and Food Engineering

College of Agricultural Engineering JNKVV Jabalpur

Cell Nutrition (Macro Nutrients)

Notes prepared by Dr Ajay Kumar Gupta, Assistant Professor, Department of Post Harvest Process and Food Engineering, College of Agricultural Engineering, JNKVV, Jabalpur 482004 (M.P.) India

1 Lecture

Cell Nutrition

- A cell's composition differs greatly from its environment.
- In order to survive, a cell must selectively remove desirable compounds from its extracellular environment and retain other compounds within itself.
- A semi-permeable membrane is the key to this selectivity.
- Since the cell differ so greatly in composition from its environment, it must spend energy to maintain itself away from thermodynamic equilibrium.
- Thermodynamic equilibrium and death are equivalent for a cell.
- All organisms except Viruses contain large amount of water (about 80%).
- About 50% of dry weight of cells is proteins, and the proteins are largely enzymes.
- The nucleic acid content of cell varies from 10% -20% of the dry weight of the cell.
- Viruses may contain nucleic acids up-to 50% of their dry weight.
- Some cells accumulate PHB up-to 90% of the total mass under certain culture conditions.
- Intra-cellular composition of cells varies depending upon

    1. Type of the cell

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2. Age of the cell
3. Composition of nutrient media

Composition of some micro-organisms

Organism	Composition (%, dry weight)			Typical population in culture (nos/ml)
	Protein	Nucleic acids	Lipids	
Viruses	50-90	5-50	< 1	10^8-10^9
Bacteria	40-70	13-34	10-15	$2x10^8$-$2x10^{11}$
Filamentous Fungi	10-25	1-3	2-4	
Yeast	40-50	4-10	1-6	$1\text{-}4x10^8$
Uni-cellular Algae	10-16	1-5	4-80	$4\text{-}8x10^7$

- Most of the products formed by organisms are produced as a result of their response to environmental conditions such as nutrients, growth hormones and ions.
- The qualitative and quantitative requirements of a cell need to be determined to optimize for growth and product formation.

Cell Nutrients

- Macronutrients
- Micronutrients

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Macronutrients	Micronutrients
• **These are needed in concentration lager than 10^{-4} M-** • Carbon • Hydrogen • Oxygen • Nitrogen • Phosphorus • Sulfer • Mg^{++} • K^{+}	• **These are needed in concentration lesser than 10^{-4} M--** • Mo^{++} • Zn^{++} • Cu^{++} • Mn^{++} • Ca^{++} • Na^{+} • Vitamins • Growth hormones • Metabolic precursors

Macro-Nutrients

Carbon Compounds

- Carbon compounds are major source of cellular carbon and energy.
- Micro-organisms are classified in two main categories on the basis of their carbon source.
- **Hetrotrophs:** Use organic carbon compounds carbohydrates, lipids and hydrocarbons as carbon and energy source.

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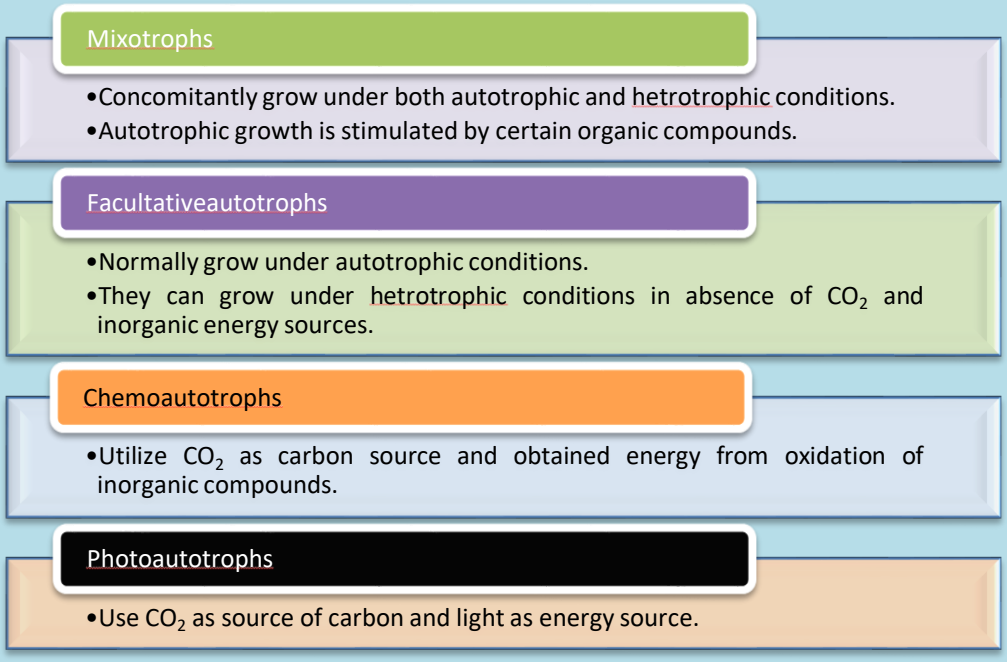
- **Autotrophs:** Use CO_2 as carbon source.

Some other categories of micro-organisms



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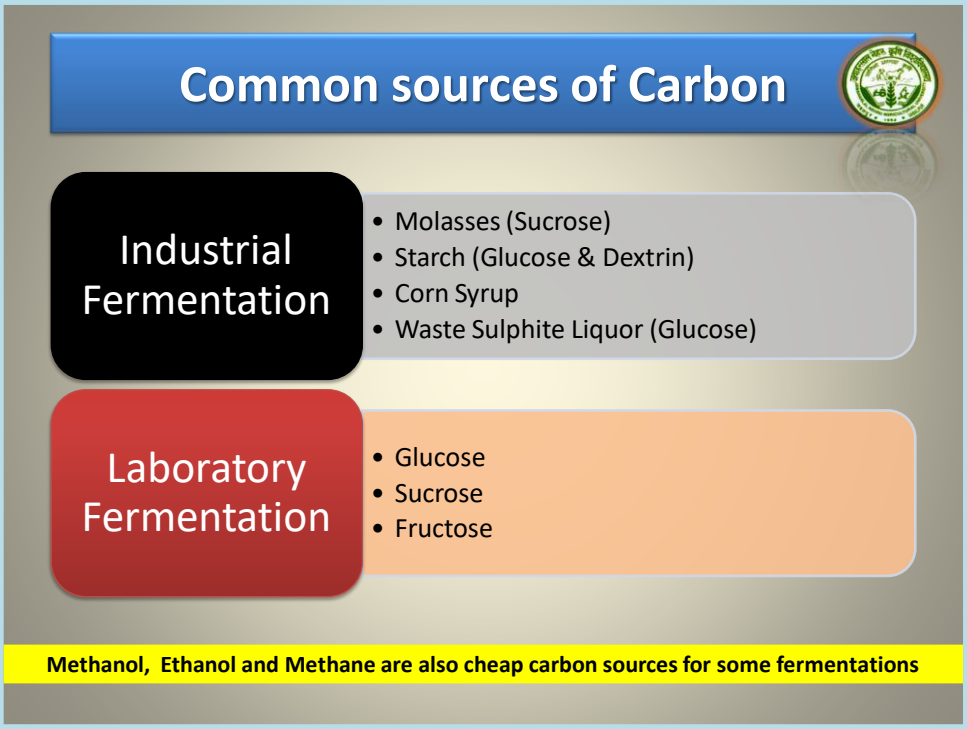

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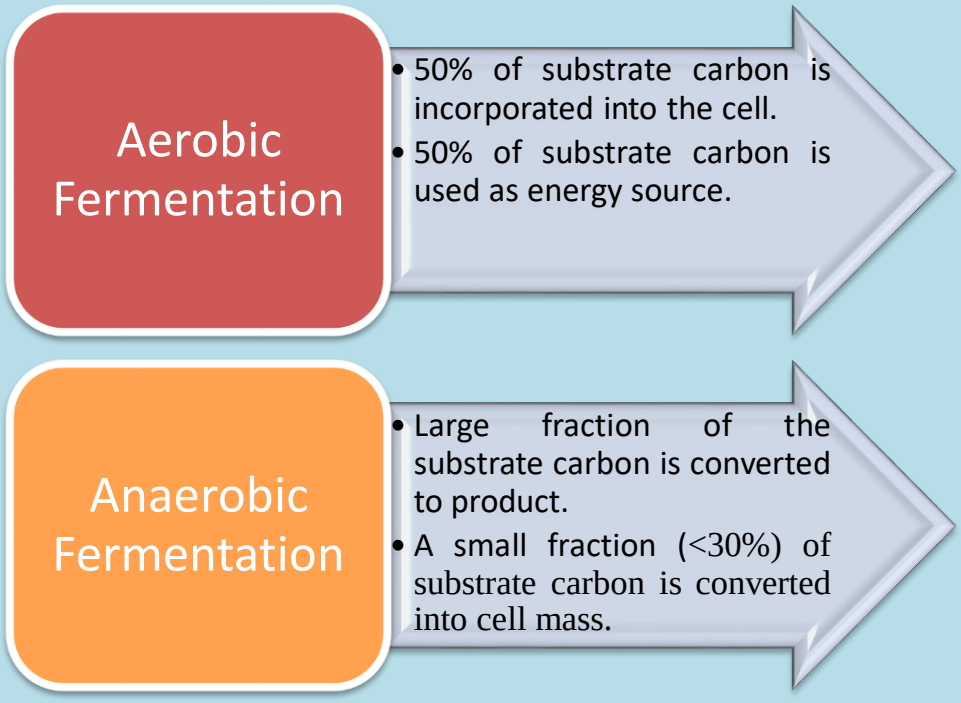
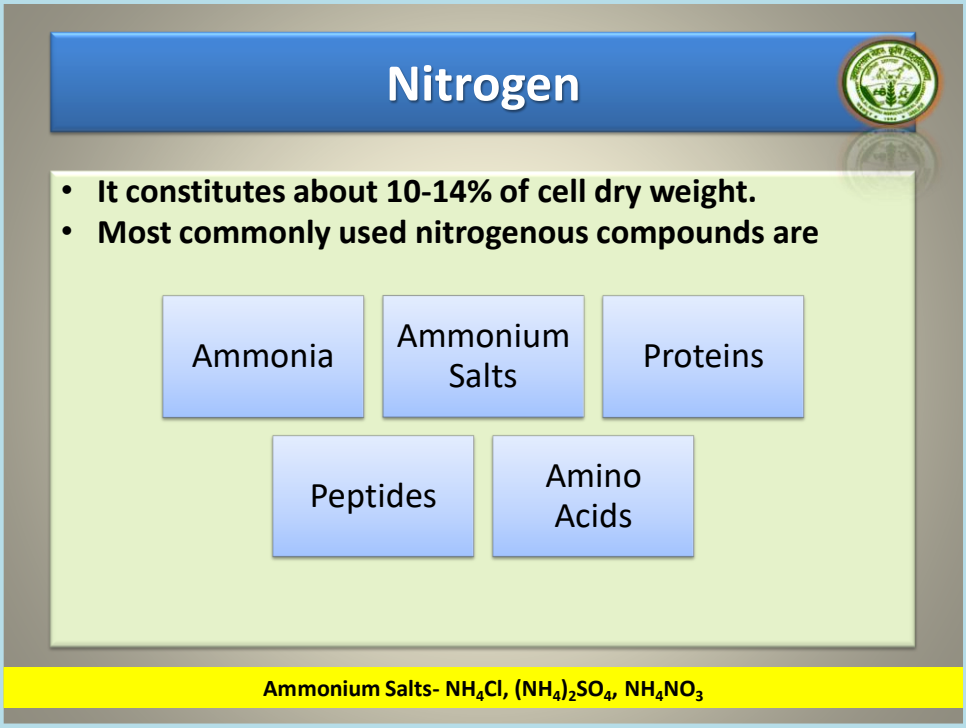


Nitrogen



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- Nitrogen is incorporated into the cell mass in the form of proteins and nucleic acids.
- Some organisms such as autotrophs and cyno-bacteria fix nitrogen from the atmosphere to form ammonium.
- Urea may also be used as nitrogen source by some micro-organisms.
- Organic nitrogen sources i.e. yeast extract and peptone are expensive compared to ammonium salts.

Some Carbon and Nitrogen sources used by fermentation Industry

Carbon Sources	Nitrogen Sources
• Starch waste (Maize & Potato) • Molasses (Cane & Beat) • Whey • N-Alkanes • Gas Oil • Sulphite waste liquor • Domestic waste • Cellular waste • Carbon beans	• Soy meal • Yeast extract • Distillers soluble • Cotton seed extract • Dried blood • Corn steep liquor • Fish soluble and meal • Ground nut meal

Oxygen

- It is present in all organic cell components and cellular water and constitutes about 20% of dry weight of cells.
- Molecular oxygen is required as terminal electron acceptor in the aerobic metabolism of carbon compounds.
- Gaseous oxygen is introduced in to growth media by spurging air or by surface aeration

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Hydrogen

- It constitutes about 8% of the cell dry weight.
- It is derived primarily from carbon compounds such as carbohydrates.
- Some bacteria such as methanogens can utilize hydrogen as an energy source.

Magnesium

- It is a cofactor for some enzymes.
- It is present in cell walls and membrane.
- Ribosomes specially require Mg++ ions.
- Magnesium is usually supplied as $MgSO_4.7H_2O$ and $MgCl_2$.

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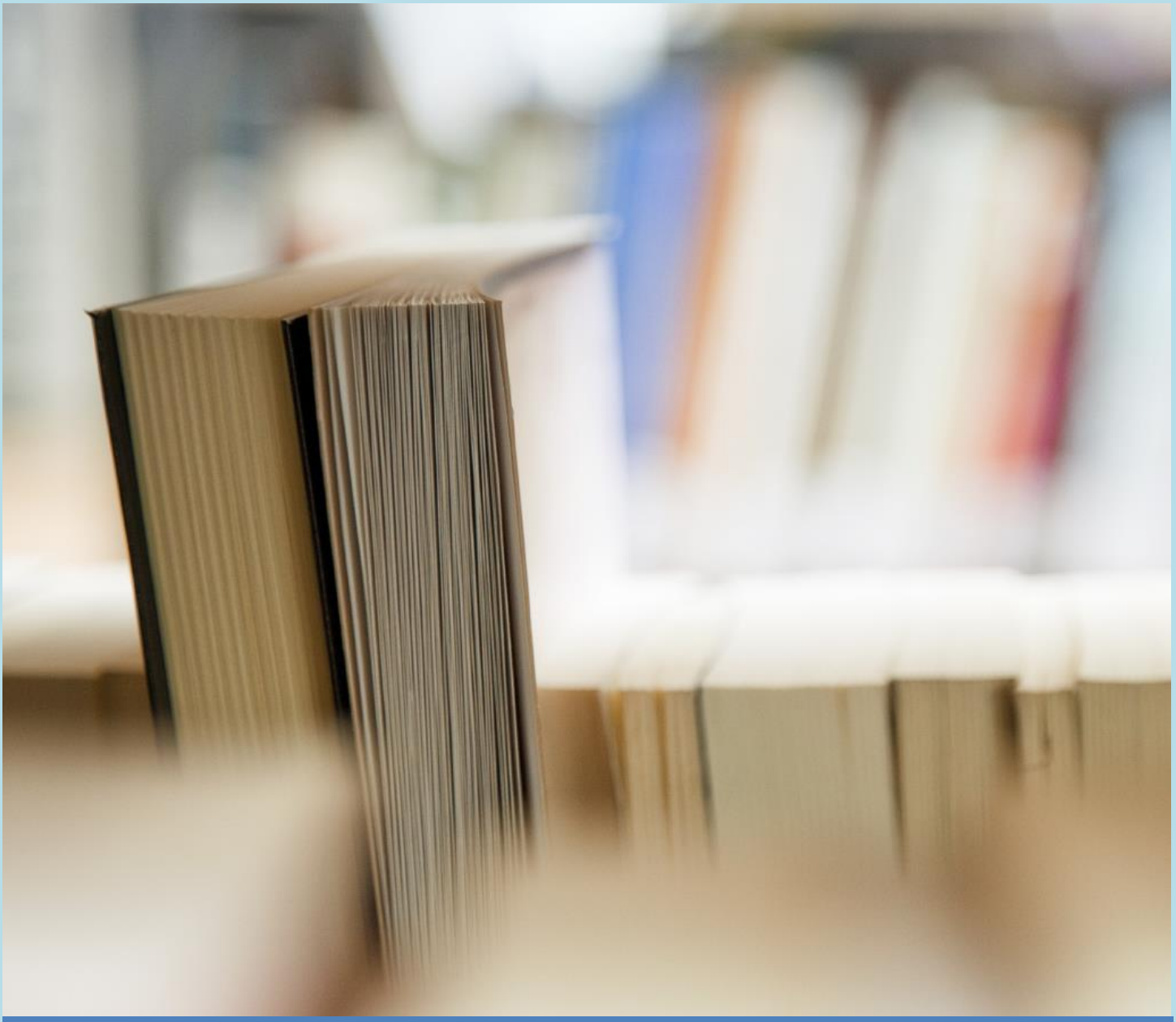

Ph.D. Process & Food Engineering
PFE 606 Bioprocess Engineering
Cell Nutrition

Micronutrients

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DEPARTMENT OF POST HARVEST PROCESS AND FOOD ENGINEERING

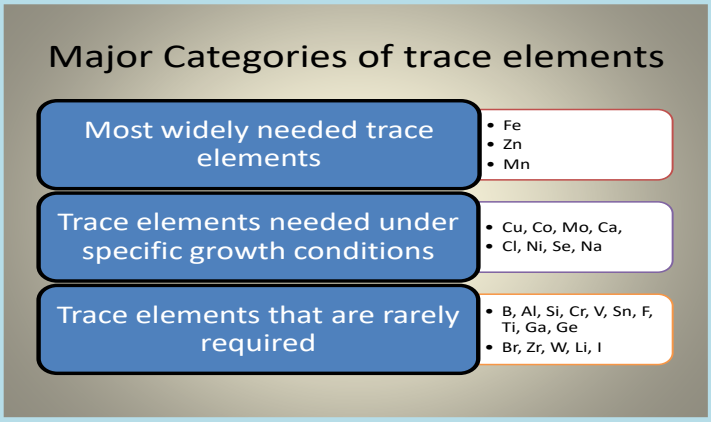
COLLEGE OF AGRICULTURAL ENGINEERING JNKVV JABALPUR

2 Lecture

Cell Nutrition

Micro-nutrients

- **Trace elements are essential for microbial nutrition.**
- **Lack of essential trace elements increases the Lag Phase and may decrease the specific growth rate and the yield.**



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Eight Macro-nutrients and some physiological functions

Elements	Physiological function	Required concentration (mol/l)
Carbon	Constituent or organic cellular material often the energy source	> 10^{-2}
Nitrogen	Constituent of protein, nucleic acids and co-enzymes	10^{-3}
Hydrogen	Organic cellular material and water	-
Oxygen	Organic cellular material and water Required for aerobic respiration	-
Sulfur	Constituents of proteins and certain co-enzymes	10^{-4}
Phosphorus	Constituents of nucleic acids, phospholipids, nucleotides and certain co-enzymes	10^{-4} to 10^{-3}
Potassium	Principle inorganic cation in the cell and co-factor for some enzymes	10^{-4} to 10^{-3}
Magnesium	Cofactor for many enzymes and chlorophylls and present in cell walls and membranes	10^{-4} to 10^{-3}

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Most widely needed trace elements

Fe

- It is present in ferredoxin and cytochrome.
- It is an important co-factor.
- It plays a regulatory role in some fermentation processes

Zn

- It is cofactor for some enzymes.
- It regulates some fermentation such as penicillin fermentation.

Mn

- It is also an enzyme cofactor.
- It plays a role in the regulation of secondary metabolism and excretion of primary metabolites.

Trace elements needed under specific growth conditions

Cu

- It is present in certain respiratory chain components and enzymes.
- It's deficiency stimulates penicillin and citric acid production.

Co

- It is present in corrinoid compounds such as vitamin B_{12}.
- Propionic bacteria and certain methanogens require cobolt.
- Mo
- It is a cofactor of nitrate reductase and nitrogenase and is required for growth on NO_3 and N_2 as the sole source of nitrogen

Ca

- It is a cofactor for amylases and some proteases.

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- It is present in some bacterial spores and in the cell walls of some cells such as plant cells.

Na^+

- It is needed in trace amount by some bacteria, especially by methanogens for iron balance.
- Sodium is important in the transport of charged species in eucaryotic cells.

Cl^-

- It is needed by some holobacteria and marine microbes which requires Na+ too.

Ni

- It is required by some methanogens as a cofactor.

Se

- Selenium is required in formate metabolism of some organisms.

Trace elements that are rarely required

- Trace elements are required in concentration of less than 10-4 M and are toxic at high concentrations such as 10-4 M.
- Some ions such as Mg++, Fe+++ and PO4-3 may pracipitate in nutrient medium and become unavailable to the cells.
- Chelating agents are used to form soluble compounds with the precipitating ions.
- Chelating agents have certain groups termed legands that bind to metal ions to form soluble complexes.

Growth Factors

- It stimulates the growth and synthesis of some metabolites.
- Vitamins, hormones and amino acids are major growth factors

Vitamins

- It usually function as co enzymes.
- Some vitamins required are thiamine, riboflavin, pyridoxin, biotin, cyanocobalamine, folic acid, lipoic acid and vit K
- These are required at the concentration 10^{-6} to 10^{-12} M.

Amino acids

- Some of all the amino acids may be required and externally supplied in concentration 10^{-6} to 10^{-13} M.

Hormones

- Higher forms of life, such as animals and plant cells require hormones to regulate their mechanisms.
- Insulin ----Animal, Auxin and Cytokinins---- plant cells

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