

### 2.3.2. Macronutrients

*Carbon* compounds are major sources of cellular carbon and energy. Microorganisms are classified in two categories on the basis of their carbon source: (1) *Heterotrophs* use organic compounds such as carbohydrates, lipids, and hydrocarbons as a carbon and energy source. (2) *Autotrophs* use carbon dioxide as a carbon source. Mixotrophs concomitantly grow under both autotrophic and heterotrophic conditions; however, autotrophic growth is stimulated by certain organic compounds. Facultative autotrophs normally grow under autotrophic conditions; however, they can grow under heterotrophic conditions in the absence of CO<sub>2</sub> and inorganic energy sources. *Chemoautotrophs* utilize CO<sub>2</sub> as a carbon source and obtain energy from the oxidation of inorganic compounds. *Photoautotrophs* use CO<sub>2</sub> as a carbon source and utilize light as an energy source.

The most common carbon sources in industrial fermentations are molasses (sucrose), starch (glucose, dextrin), corn syrup, and waste sulfite liquor (glucose). In laboratory fermentations, glucose, sucrose, and fructose are the most common carbon sources. Methanol, ethanol, and methane also constitute cheap carbon sources for some fermentations. In aerobic fermentations, about 50% of substrate carbon is incorporated into cells and about 50% of it is used as an energy source. In anaerobic fermentations, a large fraction of substrate carbon is converted to products and a smaller fraction is converted to cell mass (less than 30%).

*Nitrogen* constitutes about 10% to 14% of cell dry weight. The most widely used nitrogen sources are ammonia or the ammonium salts [NH<sub>4</sub>Cl, (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>, NH<sub>4</sub>NO<sub>3</sub>], proteins, peptides, and amino acids. Nitrogen is incorporated into cell mass in the form of proteins and nucleic acids. Some organisms such as *Azotobacter sp.* and the cyanobacteria fix nitrogen from the atmosphere to form ammonium. Urea may also be used as a nitrogen source by some organisms. Organic nitrogen sources such as yeast extract and peptone are expensive compared to ammonium salts. Some carbon and nitrogen sources utilized by the fermentation industry are summarized in Table 2.8.

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

**TABLE 2.8** Some Carbon and Nitrogen Sources Utilized by the Fermentation Industry

Carbon sources	Nitrogen sources
Starch waste (maize and potato)	Soya meal
Molasses (cane and beet)	Yeast extract
Whey	Distillers solubles
n-Alkanes	Cottonseed extract
Gas oil	Dried blood
Sulfite waste liquor	Corn steep liquor
Domestic sewage	Fish solubles and meal
Cellulose waste	Groundnut meal
Carbon bean	

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