14.3: Biological Feedstocks

Organisms have provided a huge share of the materials used by humans throughout their existence. Trees have served as sources of wood for construction and firewood. Animals provided hides and fur to protect primitive humans from Ice Age cold. The American bison was the source of food, shelter, clothing, and a wide variety of other useful items to plains-dwelling Native Americans. Protein silk is obtained from the cocoons of insects, and protein wool from sheep and related animals.

Biomass, the plant material generated from photosynthesis is the leading candidate to replace petroleum as a feedstock for the organic chemicals industry. There are several major categories of biomass that can be used for feedstock:

1. Carbohydrate, which has the general formula of approximately CH_2O. Carbohydrate is the biomass that is produced initially as glucose sugar from water and carbon dioxide during photosynthesis. It is contained in the structural parts of plants as cellulose, a biopolymer.

2. Lignin, a biological polymer with a complex structure, which occurs with carbohydrate cellulose in woody parts of plants, binding fibers of cellulose together. Relatively few uses have been found for lignin, and it poses impurity problems in extracting cellulose for feedstock use.

3. Lipid oils extracted from seeds, including soybeans, sunflowers, and corn.

4. Hydrocarbon terpenes produced by rubber trees, pine trees, and some other kinds of plants.

5. Proteins, produced in relatively small quantities, but potentially valuable as nutrients and other uses.

Biological materials used as sources of feedstocks are usually complex mixtures, which makes separation of desired materials difficult. However, in some biological starting materials nature has done much of the synthesis. Most biomass materials are partially oxidized as is the case with carbohydrates, which contain approximately one oxygen atom per carbon atom (compared to petroleum hydrocarbons which have no oxygen). This can avoid expensive, sometimes difficult oxidation steps, which may involve potentially hazardous reagents and conditions.

There are several main pathways by which feedstocks can be obtained from biomass. The most straightforward of these is a simple physical separation of biological materials, such as squeezing oil from oil-bearing biomass or tapping latex from rubber trees. Only slightly more drastic treatment consists of extraction of oils by organic solvents. Physical and chemical processes can be employed to remove useful biomass from the structural materials of plants, which consist of lignocellulose composed of cellulose and the related carbohydrate polymer hemicellulose bound together by lignin “glue.”

Carbohydrates are perhaps the most likely candidates as feedstocks for chemical processes. Carbohydrates come in several forms. Sucrose sugar, $C_{12}H_{22}O_{11}$, can be squeezed from sugar cane as sap and can be extracted from sugar beets and sugar cane with water. The exceptional photochemical productivity of sugar cane makes sucrose from this source an attractive option. Larger amounts of carbohydrates are available in starch, a polymer of glucose readily isolated from grains, such as corn, or from potatoes. An even greater source is found in cellulose, which occurs in woody parts of plants. It is relatively easy to break down starch molecules with the addition of water (hydrolysis) to give simple sugar glucose. Breaking down cellulose is more difficult, but can be accomplished by the action of cellulase enzymes.

Lipid oils are extracted from the seeds of some plants. Volatile solvents, most commonly the 6-carbon straight-chain alkane *n*-hexane, C_6H_{14}, are used to extract oils. In this process, the solvents are distilled off from the extract and recirculated through the process.

The hydrocarbon terpenes that occur in rubber trees can be tapped from the trees as a latex suspension in tree sap. Steam treatment and distillation can be employed to extract terpenes from sources such as pine or citrus tree biomass.

Grain seeds are rich sources of protein, almost always used for food, but potentially useful as chemical feedstocks for specialty applications. An exciting possibility just now coming to fruition in a practical sense is to transplant genes into plants so that they will make specialty proteins, such as medicinal agents.