To insure complete utilization of mineral nutrients may need to be added to give a C/N/P ratio of 100/15/3.

Two widely known processes for conversion of wastes to SCP are the SYMBA and the PEKILO processes. The SYMBA process converts potato wastes to SCP and consists of two stages. The first stage is for enzymatic hydrolysis of starch by *Endomycopsis* sp. and the second is for SCP production on glucose by *Saccharomyces* sp. PEKILO process is based on growth of *Paecilomyces* sp. on waste sulfite liquor.

Such waste materials can also be converted to chemicals such as ethanol for use as a fuel, solvents such as acetone/butanol, or monomers for synthesis of polymers (lactic acid). Conversion of starches to glucose and fermentable sugars is a well-established industry that uses large quantities of enzymes such as α-amylase, β-amylase, and glucoamylase. The economically feasible conversion of cellulosic wastes into fermentable sugars remains a bioprocess challenge. Many types of cellulases made by microbes can be used; new processes using genetically engineered microbes (e.g., *Trichoderma* sp., *Thermomonospora* sp., and some *Clostrida* sp.) may lead to less expensive cellulases. Acid hydrolysis can be used instead of enzymatic processes but is less environmentally friendly. The economical conversion of cellulosic wastes into products, such as ethanol, would be a major contribution to human welfare.

16.7 SUMMARY

Populations containing multiple species are important in natural ecosystems, well-defined processes, waste-water treatment, and systems using genetically modified cells. Some examples of interactions among these species are competition, neutralism, mutualism, protocooperation, commensalism, amensalism, predation, and parasitism. In real systems, several modes of interaction may be present. Mathematical analyses can be used to show that neither pure competition nor pure mutualism gives a stable steady state in a chemostat. However, spatial heterogeneity, dynamic fluctuations, and the addition of other interactions can lead to the sustained coexistence of species with competitive or mutualistic interactions.

One of the major process uses of mixed cultures is waste-water treatment. The activated-sludge system is commonly employed in treating waste waters. Such a system can be considered a chemostat with cell recycle under aerobic conditions. Alternative methods of aerobic treatment include trickling-bed filters, rotating biological discs, and oxidation ponds. Anaerobic digestion can be used to directly treat waste waters or, more commonly, to further degrade sludges from the primary and secondary treatment levels of a waste-treatment plant.

SUGGESTIONS FOR FURTHER READING

BULL, A. T., "Mixed Culture and Mixed Substrate Systems," M. Moo-Young, ed., *Comprehensive Biotechnology,* Vol. 1, Pergamon Press, Elmsford, NY, pp. 281–300, 1985.