Ethanol and some of the other by-products are inhibitory to yeast above concentrations of 5% (vol/vol). Therefore, the glucose concentration in feed solution in continuous fermentation should be less than 100 g/l, resulting in ethanol concentration in the effluent below 50 g/l. Ethanol-tolerant yeast strains are being developed to avoid ethanol inhibition. Simultaneous removal of ethanol from fermentation broth is another alternative for alleviation of ethanol inhibition.

Conventional ethanol fermentations operate in batch mode under aseptic conditions. Mechanically agitated stainless-steel reactors are used for this purpose. A reactor is filled with a nutrient medium up to 70% of its volume. After pH and temperature adjustment the reactor content is sterilized and cooled to fermentation temperature. Temperature and pH are controlled during operation, and redox potential is kept below −100 mV by using reducing agents such as Na_2S. A sterile yeast culture is prepared and used for inoculation of the reactor. A batch fermentation cycle lasts nearly 30-40 hours. Part of the yeast and aqueous medium can be recycled. Batch operation with cell recycle (the Melle–Boinot Process) results in reduced fermentation times (10 h) and improved productivities of 6 g/l h. At the end of batch operation the reactor content is emptied and yeasts are separated by filtration or centrifugation. The liquid broth is further processed for separation of ethanol by distillation.

Continuous operation in ethanol fermentations has significant advantages over batch operation. With continuous media sterilization and aseptic operation techniques, contamination problems associated with continuous operation can be eliminated. About 95% of sugar can be converted to ethanol in continuous operation with a residence time of 21 h, as compared to batch operation time of 40 h. Under optimized conditions the residence time for 95% conversion can be as low as 10 h. Continuous operation with cell recycle may increase fivefold the cell concentration in the reactor, resulting in faster conversion. Sedimentation tanks, centrifuges, or filters can be used for cell separation from the fermenter effluent. With cell recycle, the residence time for 95% conversion may be reduced to 1.6 h with a productivity of 30 g/l h for a feed glucose of 100 g/l. Multistage continuous operation with cell recycle may further improve the productivity of the process. When six fermenters in series are used without cell recycle, it is possible to obtain 95 g/l in 9 h of total residence time and a productivity of 11 g/l h.

Figure A.1 depicts the biostill process used for ethanol fermentations. This process employs continuous operation with cell recycle and a distillation column for ethanol separation. A mechanically agitated stainless-steel fermenter is used in continuous mode, and the effluent is centrifuged for yeast separation. Part of the separated yeast is recycled back to the fermenter, and the liquid medium is fed to a distillation column for separation of ethanol. Ethanol-free medum is recycled back to the fermenter. Yeast cell recycle provides high conversion rates, and liquid recycle reduces the amount of waste water generated and dilutes the feed sugar concentration down to noninhibitory levels.

Immobilization of yeast within porous or polymeric matrices results in high cell concentrations in the reactor and, therefore, high ethanol productivities. Immobilized cell reactors may be in form of packed columns or fluidized beds. Some flocculating yeast strains that settle rapidly may also be used in tower fermenters to obtain high cell concentrations.

A comparison of industrial processes used for ethanol production is presented in Table A.1.