and should be available year around. Sucrose from sugar cane or sugar beet juice, lactose from cheese whey, and maltose or dextrose from hydrolyzed starch are used as raw materials in industry. Molasses can also be used; however, its complex nature makes separation of lactic acid problematic. Dextrose from corn starch was the most commonly used raw material in the late 1950s. Other processes based on pasteurized milk (*L. bulgaricus*), dextrose from corn, glucose (*Rhizopus*), crude sorghum extract, and potato hydrolysate have also been developed. Direct hydrolysis and fermentation of corn starch by certain *Lactobacillus* species seem to be quite promising from the economical point of view. Nitrogen sources such as malt extract, corn steep liquor, barley, and yeast extract should be added to the fermentation media to improve growth and lactic acid formation.

Industrial processes are operated batchwise (Fig. A.2). Fermenters are made of stainless steel and are equipped with heat-transfer coils. Vessels are steam-sterilized before being filled with a pasteurized medium. Slow agitation to prevent settling of calcium carbonate is provided with top-mounted mechanical stirrers. Fermentation conditions are different for each industrial producer, but are usually in the range of T = 45–60°C and pH = 5–6.5 for *L. delbruckii;* T = 43°C, pH = 6–7 for *L. bulgaricus;* and T = 30–50°C, pH < 6 for *Rhizopus*. The fermentation time is 1 to 2 days for a 5% sugar source such as whey, and 2 to 6 days for a 15% glucose or sucrose source. Under optimal conditions the processing time may be reduced to 1–2 days. The rate of lactic acid formation depends on temperature, pH, sugar, nitrogen, and lactic acid concentrations. Temperature and pH control at optimum levels improves the rate of lactic acid formation. Produced lactic acid must be neutralized, usually by addition of calcium carbonate or calcium hydroxide. CO_2 is continuously released during fermentation, which creates anaerobic conditions in the fermenter. Lactic acid formation productivities are in the range of 1–3 kg/m^3 h. The yield of lactic acid at the end of fermentation is 90–95% of initial sugar concentration. Cell mass yield is usually less than 15% of initial sugar concentration; however, the yield may be as high as 30%, depending on the organism and culture conditions.

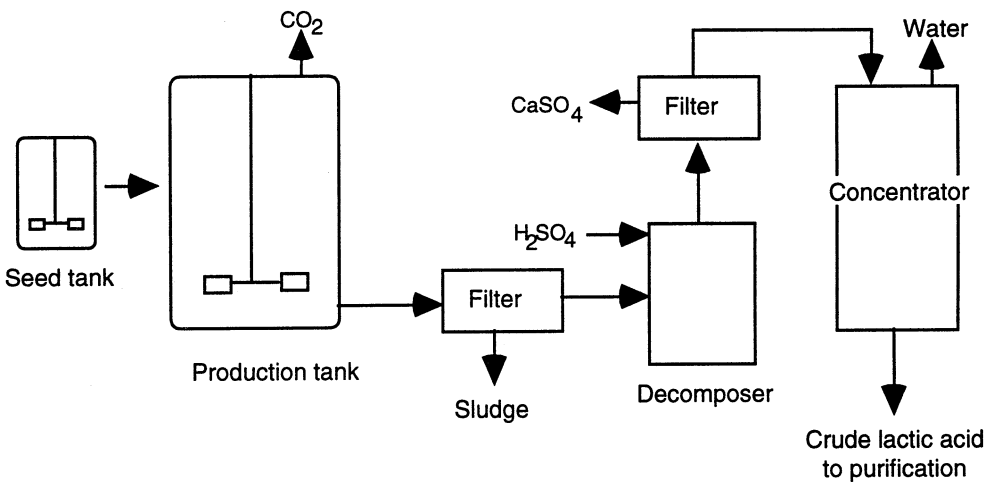

Figure A.2. Process diagram for lactic acid production.