enzyme glucoamylase to produce more dextrose from branched chains of the starch. In continuous saccharification reactors, glucoamylase is added to the 10–15 DE liquefied starch after temperature and pH adjustment and is fed through a number of reactors in series. The conditions for this step are 60°C, pH of 4.3, and holding time of 65 to 75 h. The feed contains 30 to 35% dry substance and 1 l of glucoamylase solution per ton of dry weight of starch. The product of this step contains 94 to 96% dextrose, 2 to 3% maltose, 1 to 2% higher saccharides, and 30 to 35% dry substance. Environmental conditions must be strictly controlled during liquefaction and saccharification to obtain the 94–96% dextrose that is required to obtain 42% fructose HFCS.

The dextrose syrup produced by the liquefaction and saccharification step is refined to remove ash, metal ions, and proteins that may interfere with isomerization. The dextrose syrup is filtered on rotary precoat vacuum filters to remove solids, proteins, and oil. The filtered liquor is then passed through several check and polish filters to remove traces of particles. The color in the filtrate is removed by granular activated carbon in columns. Carbon-treated liquor is filtered again and passed through ion-exchange columns to remove metal ions and ash. These columns are dual-pass cation–anion ion-exchange systems that also remove color. Deionized and decolorized dextrose syrup is evaporated to concentrate dextrose, and Mg ions are added to activate the isomerase.

Conversion of glucose (dextrose) to fructose by the enzyme glucose isomerize is accomplished in a packed column of immobilized enzyme. The reactor conditions are 55–65°C, pH of 7.5 to 8, and residence time of 0.5 to 4 h. The optimum temperature is 60°C. Temperatures higher than 60°C cause higher conversion rates and faster inactivation of the enzyme. The feed temperature may be as low as 55°C, resulting in slower conversion and enzyme inactivation rates. Microbial contamination may be a problem at temperatures below 55°C. The optimum pH for maximum enzyme activity is 8 and for stability is between 7 and 7.5. Therefore, the operating pH is adjusted for maximum stability and activity of the enzyme. The feed syrup contains 40 to 45% dry substance, 94–96% dextrose, 4–6% higher saccharides, and 4 m*M* of Mg ions as activator. The enzymatic isomerization of glucose to fructose is reversible. With 96% dextrose in the feed, the equilibrium fructose concentration in the effluent is expected to be 48%. However, the exact equilibrium is not reached with 4 h of residence time, and the effluent contains 42% fructose.

The activity of the immobilized enzyme in the column drops exponentially with time. The half-life of the enzyme is 70 to 120 days. Therefore, the residence time for maximum conversion is low for new columns with unused enzymes, and the feed flow rate should be lowered at later stages of operation to obtain 42% fructose. Usually series and parallel configurations of immobilized enzyme columns are used to compensate for activity loss of the enzyme. Parallel operation of six columns offers a good flexibility and results in good product quality. A number of process variables such as temperature, feed pH, and flow rate may be varied to obtain uniform product quality. Constant fructose levels are usually achieved by automatic back blending controlled by a polarimeter. Columns must be replaced two or three times a year. The cost of the enzyme is a major part of the operating cost. By improving the stability and activity of the enzyme, the cost of isomerization may be reduced significantly.

HFCS produced by isomerization of dextrose syrup can be further refined to remove color and ions by carbon treatment and ion exchange, respectively. The refined 42% HFCS is evaporated for shipment to yield 71% solids.