are aerated in the bottom by perforated horizontal pipe spargers. Stirred tanks utilized for yeast production typically have oxygen transfer rates of 1 mole O_2/l h and $K_L a$ of 600 h^{-1}. Temperature control is accomplished by cooling coils, and pH is controlled by addition of acid or base. Dissolved-oxygen concentration and foam are also controlled. Some plants are computerized and automatically controlled.

To avoid the Crabtree effect, production of bakers' yeast is performed in fed-batch mode. The inoculum is prepared in smaller tanks and is added to the production fermenters. Multistage fermenters can be used for production. Diluted molasses, ammonium or urea, phosphoric acid, and mineral salts are stored in different tanks. The process starts batchwise after filling and sterilization of the fermenter content. Intermittent feeding of continuously sterilized nutrients starts when the initial charge of nutrients is depleted. The feeding rates of nutrients are adjusted to maximize growth rate. Dissolved-oxygen monitoring can be utilized to evaluate the metabolic activity of yeast and is the basis for feedback control systems for nutrient addition.

After 20 to 30 h of culture, the broth is transferred to centrifuges for separation of yeast. The cells are washed several times to remove inert solids. Centrifugal separation results in a light colored cream with up to 22% solids from yeast. The cream is stored in agitated tanks at 2–4°C, and part is used for seeding additional fermentations. Bakers' yeast can be sold in the form of cream, in compressed form (30% yeast solids), or dried (95% yeast solids). Filter press or rotary vacuum filters are used to concentrate cream. The filtered yeast may be mixed with emulsifiers prior to being extruded into yeast cakes or packaged in large paper bags. Fresh bakers' yeast may be marketed as free-flowing particles by adding ingredients such as modified starch or micronized cellulose.

To produce active dry yeast, the filtered yeast cake is extruded into particles that are dried in a hot air stream. Drying temperature, drying rate, and final moisture content of the dried yeast should be controlled during drying. The drying temperature is usually 45°C. Most of the vegetative yeast cells are killed at temperatures above 50°C. Drying time may vary from 20 min to several hours, depending on the type of drier used. The final moisture content of yeasts after drying is about 5–10%. Several types of driers can be used. The Roto–Louvre drier is an empty cylinder rotating at 1–4 rpm. Heated air at 50–60°C is blown to the cylinder containing yeast particles. The drying temperature is 45°C and the duration is 10–15 h. In fluidized bed driers, hot air (50–60°C) is blown from the bottom of the column to keep the cells suspended in air. The drying temperature and time are 45°C and 1–2 h, respectively. Spray driers are the most widely used. A suspension with 10–20% yeast is atomized into a drying chamber and dried with hot air. The drying temperature and time are 50°C and 10–20 min, respectively. Product quality depends mainly on gassing activity of yeast. Presence of certain carbohydrates such as trehalose or glycogenin increases the gassing activity of yeast. Highly stable active dry yeast can be obtained from cultures with a high protein content. Fluidized bed or spray driers yield fine yeast particles of 0.2–2 mm with high protein content and high gassing activity.

A.2.3. Production of Penicillins

Penicillin was discovered by Alexander Fleming (see Chapter 1). Different penicillins are produced by different strains of *Penicillium.* Chemical structures of penicillins G and V are given in Fig. A.4.