dict and Manning, and to produce the necessary vacuum he utilized an electrically driven vacuum pump instead of displacement of air with ethyl ether [12].

In the 1920s, lyophilization was established as a stabilizing process for heat-liable materials [13]. Interestingly, in 1925 the Dry Ice Corporation of America first trademarked the name Dry Ice [9]. In 1927, the first US patent was issued to Tival which made a reference to the drying of frozen materials under vacuum conditions [13]. The industrial applications of freeze-drying do not appear to have been appreciated prior to patents of Tival in 1927. In 1934, a US patent was issued to Elser who described drying equipment that replaced Shackell's sulfuric acid desiccating system with a cold trap chilled with dry ice.

Development and Popularity of Lyophilization in Food Products

In 1938, the freeze-dried coffee was first manufactured, which led to the development of powdered food product [9]. The 1940s marked great development. The first commercial use of the freeze-drying was reported. Equipment and techniques were developed to supply blood plasma and penicillin to the armed forces during World War II [14]. Greaves was the first to show scientific insight into the drying process by identifying the key operating parameters [15].

From 1950s to 1960s, with increasing popularity of lyophilized food products, further development in freeze-drying process was realized. In 1960, the coining of the term lyophilization is generally attributed to LR Rey who described the porous nature of the dried product and its "lyophil" characteristics to rapidly reabsorb the solvent and restore the substance to its original state [6, 11].

Freeze-drying which requires the use of special equipment, is called a freeze-dryer or lyophilizer. It contains a large chamber for freezing and a vacuum pump for removing moisture or sublimation of ice. Since the 1960s, more than 400 different types of freeze-dried foods have been commercially manufactured. Lettuce and watermelon are considered the two worst candidates for freeze-drying, not surprising, due to its very high water content [9].

Freeze-dried coffee is the best-known freeze-dried product. Nestle company invented freeze-dried coffee, when asked by Brazil to find a solution to their coffee surpluses. Nescafe, first introduced in Switzerland, was Nestlé's own freeze-dried coffee product. After Nescafe, the Taster's Choice Coffee, another famous freeze-dried product is derived from the patent issued to James Mercer. During 1966–1971, Mercer at Hills Brothers Coffee Inc. in San Francisco led the development of a continuous freeze-drying capability and was granted 47 US and foreign patents [9].

It was after the World War II that drying was converted into an industrial method utilizing the tray-type lyophilizer to improve the shelf life for pharmaceuticals. Also, for instant coffee granules, the tray-type freeze-dryer was used for the sublimation of the water.

In 1968, Whirlpool Corporation under contract from NASA for the Apollo missions developed the freeze-dried ice cream, well known as astronaut's ice cream