that the electrostatic attraction between the cationic TTAB and the anionic ascorbic acid (at pH 7.4) brought the ascorbic acid in close contact with the surface of the micelle [222]. Similar experiments were carried out to examine the peroxidation of PC liposomes in the presence of antioxidants [222]. The peroxidation of PC liposomes was initiated by the addition of MeO–AMVN, and the ability of several antioxidants to inhibit peroxidation was tested. PC liposome peroxidation was monitored by measuring the formation of lipid hydroperoxides. PC liposome peroxidation was decreased in the presence of antioxidants as indicated by the decreased hydroperoxide formation. Antioxidants, such as PMC, that were able to efficiently partition into the bilayer were able to suppress PC oxidation most efficiently [222]. We have observed related phenomena when using fluorescent probes to monitor lipid oxidation. In our previous studies on lipid oxidation, we observed that water-soluble probes were not able to accurately monitor oxidation occurring in the suspended lipid particles [115].

Lyophilized Lipid Formulations

Particularly in the 1960s and 1970s, an increased interest in the stability of freeze-dried food products arose. A number of studies were conducted that focused on the factors that would deleteriously impact the stability of lyophilized food products. These studies focused on lipid peroxidation in lyophilized foods and a variety of experimental systems were used to investigate the effect of moisture content, transitional metals, and antioxidants. Interested readers are referred to several studies [198–204] which utilized lyophilized salmon and dehydrated milk as well as an experimental system comprised by methyl linoleate, cellulose, and glycerol to study lipid oxidation. However, because of the significant differences and complexity in these experimental systems, this work will not be discussed. Years later, a unique study conducted by Mouradian et al. [234] investigated the chemical stability of lipid-based vesicles over the course of 49 days. Sarcoplasmic reticulum (SR) vesicles prepared from lobster tail muscle were isolated and lyophilized. These vesicles were not a pure lipid system and contained proteins inherent to the SR. The oxidative degradation of these lipid-based vesicles was assessed by measuring the accumulation of lipid hydroperoxides and secondary oxidation products (i.e., aldehydes) with the TBARS assay. Oxidation was expected to be a major degradation pathway due to the presence of polyunsaturated lipids in the SR membrane. The effect of varying the concentration of trehalose (0–2 g trehalose/gram membrane) was tested, and it was observed that the trehalose content of SR vesicle samples had no effect on oxidation. However, the moisture content, which was dictated by the relative humidity samples were exposed during storage (0 and 35%), and exposure to light had significant effects on the stability of the SR vesicles. As might be expected, exposure to light correlated with increased hydroperoxide accumulation. Surprisingly, a greater concentration of secondary oxidation products was detected in the samples with lower moisture content (exposed to 0% relative humidity). Mouradian et al. [234] proposed that the secondary oxidation products were less stable chemically in samples with a higher moisture content preventing their accumulation and subsequent detection.