



FIGURE 11 Comparison of product temperature and drying rate for edge versus center cylinders.

product temperature between inner and outer samples after sublimation has been completed. When the sublimation phase is completed, the inner samples equilibrate to the shelf temperature in a manner similar to that observed for typical vial products. However, the outer (edge) samples are observed to equilibrate at a significantly higher temperature (as high as 5°C above the shelf temperature). This illustrates the degree to which the radiative heat from the chamber walls is influencing the product temperature of the edge samples due to the distance between the cake and the lyophilizer shelf. This heterogeneity in product temperature can differ significantly depending on the syringe holder type, the dryer design, and the size of the freezer-dryer. It has been observed that syringe racks providing greater spacing between cartridges can result in sublimation behavior in syringes (across the batch load) similar to freeze-drying in glass vials (21). Properly designed development experiments are the key to appropriately guide the freeze-dry cycle development and subsequent scaling up of the process.

Secondary Drying

The secondary drying phase of the freeze-dry cycle consists of the removal of unfrozen water by desorption. Once the primary drying phase has been