Free Volume: Moisture Migration into Sugar Glasses

Microspectroscopy techniques that measure moisture movement into sugar glasses may help candymakers enhance the long-term stability of hard candy.

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Stickiness and graining are common problems associated with high humidity during storage of hard candies. Although the molecules in the glassy structure of a hard candy are tightly packed, the random nature of the molecular organization means there are spaces between the sugar molecules — the free volume — into which smaller molecules like water can diffuse. Water molecules from the air slowly penetrate into this free volume between sugar molecules in the hard candy glass, plasticizing the matrix as the water content increases. Since penetration of the water molecules into the glassy matrix is slow compared to sorption of water molecules at the air surface of the candy, a backlog of water molecules builds up at the surface. This causes formation of a distinct moisture front, which slowly penetrates into the candy, leaving behind a layer of higher water content that becomes sticky and potentially can crystallize.

Recent studies have quantified the rate of penetration of the moisture front into a sugar glass, documenting the effects of composition, relative humidity and temperature on moisture penetration. Using a simple model sugar glass in a one-dimensional arrangement, the water concentrations at different depths into the glass during storage have been measured by two spectroscopic techniques. The results confirm the existence of a fairly sharp penetration front moving slowly into the glass, with the rate of penetration of the moisture front increasing with higher storage RH, as expected. Typical sugar composition (i.e., corn syrup type and ratio) for hard candies seemed to have little effect on the rate of movement of the penetration front, at least for the systems studied.

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HARD CANDY

Hard candy is made by cooking a sugar and corn syrup mixture to high temperature (149° to 152°C; 300° to 305°F) to reduce water content to about 2 to 4 percent. At these high cook temperatures, the concentrated sugar syrup is still sufficiently fluid (low enough viscosity) to be pumped, deposited into moulds or poured onto cold tables. In the liquid state, the sugar molecules are still quite mobile and free to move around quite easily. As the sugar mass cools, however, the ability of the molecules to move around from place to place (translational mobility) and even to move around in three-dimensional space (rotational mobility) decreases, as evidenced by a significant increase in viscosity. At some temperature during cooling, the sugar mass changes from liquid to glassy state. At temperatures below ➤