activity of products, the growth of microorganisms, when present, can be controlled as well.

The a_w also has an effect on the chemical processes within a product or formulation. Lowering the a_w may increase chemical stability. The activity of proteins and enzymes, which may lead to chemical changes, requires maintenance of specific a_w levels that can be controlled or minimized. Browning, or Maillard reactions, can be controlled by altering a_w as well.

In addition to the benefits of increased microbiological and chemical stability, reduced need for chemical preservatives may be another important benefit. Pressure from regulatory bodies provides a constant challenge to the pharmaceutical industry to limit, and eliminate where possible, the use of chemical preservatives. Controlling a_w is a means of natural preservation that can be used alone, in combination with lower amounts of chemical preservatives, or with other restrictive attributes such as pH. Using multiple approaches can further reduce proliferation of microorganisms.

Freezing, freeze drying, salting, syruping, and drying are preservation methods that take advantage of lowering a_w. These methods either bind or eliminate the available water in a product. While some resistance/sensitivity variability within a microorganism population will always exist, micro-organisms have not been shown to develop a tolerance to low a_w levels as they can to chemical means of preservation.

Recommendations & Rationale for Recommendations

Ideally, water activity should be evaluated early in the product development process. Low a_w can be achieved by limiting the amount of water added to a product during formulation, driving off water, or binding remaining water.

Water is often used to dissolve product constituents. When limiting water in the formulation is not possible, it may be driven out of the formulation or rendered inactive by binding it. Driving off water occurs on a routine basis in the pharmaceutical industry through heating, drying, and freeze-drying processes.

Binding of available water occurs through the use of solutes (e.g. sugars, salts, fatty acids, glycols, etc.). Different solutes provide different a_w results. Salts are typically more effective at lowering a_w than sugars.

Though a_w is a key component, it can not be solely relied upon for ensuring the microbial quality of products. Other factors that affect microbial quality of the final product include quality of ingredients, method of manufacture, quality of the manufacturing environment, equipment sanitization, final packaging, and storage. Low a_w does not necessarily kill microorganisms, but limits or halts proliferation. Any microorganisms present have the potential for growth should the proper environment become present.

Once ingredients are qualified, a_w testing can assist in verification of the potential for microbial growth. Raw materials of natural origin (*e.g.*, starch, sugars, proteins, etc.) can possess higher microbial populations than synthetic materials. [5] Manufacturing holding times of aqueous solutions, wet processes, and cleaning of equipment play important roles in controlling any microbial growth present in starting materials.

