Water Activity and Spices

Introduction

Spices are defined as products derived from vegetables or mixtures thereof that are free from other material and are used to provide flavorings, seasoning, and aroma to foods (Peter 2001). In general, they are used to enhance the taste or aroma of food. Spices are strong antioxidants and have other beneficial qualities.

Herbs are derived from the leaves of a plant while spices are taken from all parts of a plant other than the leaves. Common herbs include basil, dill leaves, tarragon, and thyme. Common spices include cayenne pepper, black pepper, paprika, and cinnamon. Spices are conventionally classified as hot, mild, and aromatic.

Spices have been used and traded for thousands of years. They have traditionally been processed and traded as dry products, usually dried by the sun (Muggeridge and Clay 2001). The quality indices of spices are focused on maintaining safety, preventing adulteration, and assuring performance. Standards are set by the American Spice Trade Association (ASTA) and the European Spice Association (ESA). ASTA or ISO Standard testing procedures are recommended to measure quality indices. It is also recommended that spice manufacturers use Hazard Analysis and Critical Control Point (HACCP) programs for their quality assurance system.

Moisture Analysis in Spices

ASTA and ESA list both moisture content and water activity as necessary moisture measurements, however only moisture content values are specified in the standards. Water activity specifications should be agreed upon between the buyer and seller. Conversely, water activity is considered a critical control point for HACCP plans while moisture content is not. Water activity and moisture content are complementary and together provide a complete moisture analysis. It is critical to understand the difference between the two measurements and their role in the safety of spices.

The terms moisture content and water content are often used interchangeably and represent a measure of the quantity of water in a product. Moisture content provides valuable information about yield and quantity, making it important from a financial standpoint. In addition, moisture content provides information about texture since increasing levels of moisture provide water mobility and lower the glass transition temperature. Water content does not provide information about microbial safety.

Water activity (ISO21807) represents the energy status of water in a system. It is equal to the relative humidity of the air in equilibrium with a sample in a sealed chamber. It is defined as the vapor pressure of water in a sample divided by the vapor pressure of pure water at the sample temperature.

Water activity, not moisture content, predicts safety and stability with respect to microbial growth, chemical and biochemical reaction rates, and physical properties. Figure 1 shows stability in terms of microbial growth limits and rates of degradative reactions as a function of water activity.

By measuring and controlling the water activity, it is therefore possible to: a) predict which microorganisms will be potential sources of spoilage and infection, b) maintain the chemical stability of spices, and c) optimize the physical properties of dry spices such as texture and flow properties. Ancient civilizations learned that if they dried spices it would preserve them and extend their shelf life. They did not realize that the preservation was the result of lowering water activity.

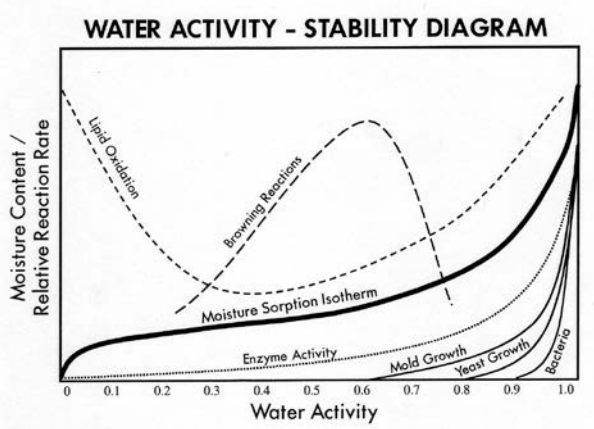

Figure 1. Water activity stability map relating the rate of many degradative reactions that reduce shelf life to water activity level.

Microbial Growth

Water activity, not moisture content, determines the lower limit of "available" water for microbial growth. Since bacteria, yeast, and molds require a certain amount of "available" water to support growth, designing a product below a critical a_w level provides an effective means to control growth. Water may be present at high content levels in a product, but if its energy level is sufficiently

low, the microorganisms cannot remove the water to support their growth.

Water activity may be combined with other preservative factors (CCPs), such as temperature, pH, redox potential, etc., to establish conditions that inhibit microorganisms and ensure safety in a HACCP plan. However, water activity is often the most important factor. The water activity level that limits the growth of the vast majority of pathogenic bacteria is $0.90a_w$. $0.70a_w$ is the limit for for spoilage molds. The lower limit for all microorganisms is $0.60a_w$.

Mold spoilage is a common problem in spices, but it is impossible to determine if a product will mold using moisture content data alone. Controlling water activity to levels below $0.70a_w$ will assure that mold will not spoil a shipment of spices. Table 1 lists the water activity limits for growth of microorganisms significant to public health. Table 2 shows the water activity of several common spices and the moisture content specifications listed by ASTA and ESA. The moisture content values themselves provide very little information. However, a comparison of tables 1 and 2 illustrates that these spices would be considered microbially safe.

Table 1. Water activity growth limits for common spoilage organisms. These growth limits were determined with all other growth factors being optimal and represent worst case scenarios.

Water Activity Limits for Growth of Microorganisms

Water Activity	Microorganism
0.97	*Pseudomonas aeruginosa*
0.95	*Bacillus cereus, Clostridium botulinum,* Type A, *Escherichia coli, Clostridium perfringens, Lactobacillus viridescens, Salmonella* spp.
0.94	*Enterobacter aerogenes*
0.93	*Micrococcus lysodekticus, Rhyzopus nigricans*
0.92	*Mucor plumbeus, Rhodotorula mucilaginosa*
0.90	*Bacillus subtilis, Saccharomyces cerevisiae*
0.86	*Staphylococcus aureus*
0.84 – 0.81	*Paecilomyces variotti, Penicillium chrysogenum, Aspergillus fumigatus, Penicillium glabrum*
0.78 – 0.75	*Aspergillus flavus, Aspergillus niger, Halobacterium halobium*
0.62	*Zygosachharomyces rouxii* (osmophilic yeast)
0.61	*Xeromyces bisporus* (xerophilic fungi)
<0.60	No microbial proliferation

Adapted from Beuchat 1981

Table 2. Water activity of common spices.

Product	Water Activity*	ASTA Specified Moisture Content[a]
Black Pepper	0.409	12%
Onion Powder	0.351	6%
Cayenne Pepper	0.435	10%
Cinnamon	0.587	14%
Garlic Salt	0.413	6%

* Water activity values were measured at 25 °C.

[a] Values taken from Peter 2001

Chemical/biochemical reactivity

Water activity influences not only microbial spoilage but also chemical and enzymatic reactivity. Water may influence chemical reactivity in several different ways: it may act as a solvent, reactant, or change the mobility of the reactants by affecting the viscosity of the system. In non-enzymatic browning and lipid oxidation, as the water activity level is lowered the rate of chemical degradative reactions typically decreases (see fig. 1). The flavor and odor enhancing properties of spices can be altered by chemical breakdown and lowering water activity can slow down these reactions and increase the shelf life of the spice.

Physical Properties

Controlling water activity in spices maintains proper product structure, texture, stability, density, and rehydration properties. Knowledge of the water activity of spices as a function of moisture content and temperature is essential during processing, handling, packaging and storage to prevent the deleterious phenomena of caking, clumping, collapse and stickiness. This is especially true for spices commonly processed as amorphous powders. From Table 2, ASTA and ESA specifications for moisture content list a lower moisture content of 6% for onion and garlic powder. They also note that lower moistures may be needed to maintain flow properties but without specifying what moisture content level will keep the powders free flowing. A specific critical water activity above which powdered spices will become susceptible to caking and clumping can be determined and used as a process and storage control point. If the water activity of the material is maintained at values below the critical water activity, the product will maintain its flow properties.

Conclusion

Water activity is a critical control point for the safety and quality of spices. It is easily measured using highly accurate instrumentation and should be an integral part of the quality control system for any spice manufacturer. For more information about measuring the water activity of spices or determining critical water activities for spice quality and safety, please contact Decagon Devices.

Reference List

Beuchat, L. R. "Microbial stability as affected by water activity." Cereal Foods World 26.7 (1981): 345-49.

Muggeridge, M. and M. Clay. "Introduction." Handbook of Herbs and Spices. Ed. K. V. Peter. 1st ed. Cambridge, England: Woodhead Publishing Limited, 2001. 13-21.

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