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Water Activity (a_w) in Foods

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WATER ACTIVITY (a_w) IN FOODS

DEFINITION

The water activity (a_w) of a food is the ratio between the vapor pressure of the food itself (p), when in a completely undisturbed balance with the surrounding air media, and the vapor pressure of distilled water under identical conditions ($p*$), i.e., $a_w = p/p*$. A water activity of 0.80 means the vapor pressure is 80 percent of that of pure water. The water activity increases with temperature. The moisture condition of a product can be measured as the equilibrium relative humidity (ERH) expressed in percentage or as the water activity expressed as a decimal.

Most foods have a water activity above 0.95 and that will provide sufficient moisture to support the growth of bacteria, yeasts, and mold. The amount of available moisture can be reduced to a point which will inhibit the growth of the organisms. If the water activity of food is controlled to 0.85 or less in the finished product, it is not subject to the regulations of 21 CFR Parts 108, 113, and 114.

SORPTION BEHAVIOR

The bacterial cell can only transfer nutrients in and waste materials out through the cell wall. The materials, therefore, must be in soluble form to permeate the cell wall. A portion of the total water content present in food is strongly bound to specific sites and does not act as a solvent. These sites include the hydroxyl groups of polysaccharides, the carbonyl and amino groups of proteins, and others on which water can be held by hydrogen bonding, by ion-dipole bonds, or by other strong interactions. The binding action is referred to as the sorption behavior of the food. The most successful method for studying the sorption properties of water in food products has been the preparation of "Sorption Isotherms," or curves relating the partial pressure of water in the food to its water content at constant temperature. The same practice is followed to study curves relating water activity under equilibrium conditions to water content.

Two basic methods can be used to obtain the constant temperature sorption curves. In the first method, food of known moisture content is allowed to come to equilibrium with a small headspace in a tight enclosure and partial pressure of water activity is measured manometrically, or relative humidity is measured using a hyqrometer. Water activity is equal to equilibrium relative humidity divided by 100: (a_w = ERH/100) where ERH is the equilibrium relative humidity (%). Relative humidity sensors of great variety are available for this purpose, including electric hygrometers, dewpoint cells, psychrometers, and others.

A second basic method for preparing isotherms is the exposure of a small sample of food to various constant humidity atmospheres. After equilibrium is reached, the moisture content is determined gravimetrically or by other methods. A number of saturated salt solutions are available for this purpose. Saturated salt solutions have the advantage of maintaining a constant humidity as long as the amount of salt present is above saturation level. Salt slushes and solutions of glycerol or sulfuric acid are among those commonly used.

Knowledge of sorption behavior of food is useful in concentration and dehydration processes for two reasons:

1. It is of importance in design of the processes themselves; because it has an important impact on the ease or difficulty of water removal, which depends on the partial pressure of water over the food and on the energy of binding of the water in the food.
2. Water activity affects food stability and therefore it must be brought to a suitable level at the conclusion of drying and maintained within an acceptable range of activity values during storage.

Products containing free water give off moisture in vapor form to the air in the environment, only when the vapor pressure in the air is below that of the product. The vapor pressure of a salt or sugar solution is reduced in comparison to that of pure water. The amount of vapor in the surrounding air generally is measured as relative humidity. At the equilibrium point, water is neither given off nor absorbed. The vapor pressure of the food product then becomes identical to that of the surrounding air.

MEASUREMENT EQUIPMENT

The equipment suitable for the measurement of water activity can be the same as that used for the measurement of relative humidity provided that the sensing element used can be made captive or otherwise isolated with a sample of the product to be measured. A basic measuring technique utilizes a sealed dish or container with the sensor mounted above the test sample.

For initial screening purposes, all FDA district laboratories are equipped with the Abbeon a w-Value Analyzer (a hair hygrometer). Samples can be tested in duplicate. The instruments are used to set up a reference chart with data obtained from checks of reliable humidity generators. Salt slushes of known a_w values such as sodium chloride, potassium nitrate, and potassium sulfate can be used. These salts will give a range of water activity (at 25 °C) from 0.758 to 0.969. The results of this test are an approximation which should then be confirmed by measurement, using pressure equilibrium techniques in which the sample is allowed to come to equilibrium with a reference standard, such as a microcrystalline cellulose (MC). Electronic instruments suitable for confirmation tests are:

1. Beckman Hygroline Moisture Meter; Nova Sina/Rotronic Moisture-Humidity Meters
2. Hygrodynamic Hygrometer

3. WeatherMeasure Relative Humidity System

The critical factors in the control of water activity as an adjuvant in preservation are the ingredients in the final product and their effect on water binding capacity which is measured by the ERH (water activity, a_w).

In determining the ERH (a_w) several hours are required for the water vapor (relative humidity) to reach equilibrium in the headspace above the food in the closed container. Therefore, the formulation of the product to give the required a_w must be predetermined and very accurately compounded at the time of packing. It is necessary for the analyst to ensure that the temperature of the supernatant air above the sample be closely controlled, as even a slight difference in temperature in this area can result in a significant change in water activity reading. Stoloff (1978) states that at 25 °C, a 0.1 °C difference between the solid or liquid sample and the supernatant air will result in an approximate 0.005 difference in water activity measurement.

Allowing the temperature between the sample air interface and the supernatant air to vary, for example, by 1 °C (approximately 1.8 F) could result in a difference in a_w reading of 0.05. Considering that the minimum a_w for the growth of C. botulinum is approximately 0.93, such a temperature differential could result in an erroneous reading for the sample of less than 0.93. Thus, the necessity of ensuring a suitable temperature control mechanism for the containment vessel (air cabinet or water bath) in which the testing chambers (e.g., glass jars) contain the sample repose.

REGULATIONS

The water activity level of 0.85 is used as a point of definition for determining whether a low-acid canned food or an acidified food is covered by the regulations. Low-acid canned foods can be preserved by controlling water activity at levels above 0.85. The minimum a_w level for the growth of C. botulinum is approximately 0.93. Depending on various product characteristics this minimum level can be as high as 0.96. The regulations (21 CFR 113.3(e) (1) (ii)) state that commercial sterility can be achieved by the control of water activity and the application of heat. The heat is generally necessary at a_w levels above 0.85 to destroy vegetative cells of microorganisms of public health significance (e.g., staphylococci) and spoilage microorganisms which can grow in a reduced a_w environment. (See also the following other sections of the regulations which deal with a_w controlled products:

21 CFR 113.10 - Attendance at an approved school giving instruction appropriate to the preservation technology involved.
21 CFR 113.40(i) - Equipment and procedures for thermal processing of foods where critical factors such as water activity are used.
21 CFR 113.81(f) - Additional factors to be controlled to prevent the growth of microoganisms not destroyed by the thermal process.
21 CFR 113.100(a) (6) - Record keeping requirements for a_w determinations.

Some examples of water activity controlled low-acid canned foods, that may have an a_w of greater than 0.85, are: canned cake, bread, bean paste, some chutney, salted vegetables, salted fish, guava paste, lupini beans, syrup, toppings, puddings, and some oriental specialty sauces. Water activity is usually controlled by the use of salt or sugar. There are situations where routine a_w determinations need not be made during production. For example, if salt is the preservative, percent salt determinations alone may be sufficient to document control of water activity and commercial sterility. However, the processor or the processing authority would need to have data which consistently relates salt levels in the particular product to a_w levels. Water activity could also be controlled by formulation as long as the formulation is related to a given a_w level by sufficient data. Since changes in ingredients suppliers may change the a_w of the finished product, periodic a_w determinations by the processor would be appropriate.

WATER ACTIVITY (a w) OF SOME COMMON FOODS

Liverwurst	0.96
Cheese Spread	0.95
Red Bean Paste	0.93
Caviar	0.92
Fudge Sauce	0.83
Soft Moist Pet Food	0.83
Salami	0.82
Soy Sauce	0.80
Peanut Butter 15% total moisture	0.70
Dry Milk 8% total moisture	0.70

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