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WATER ACTIVITY PRINCIPLES

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Water and Food Safety

One of the oldest forms of preserving foods is drying or desiccation. When first applied there was little understanding of why removing moisture from food had the effect of extending its shelf life. The table below shows the typical (TOTAL) water content of certain food products and categories: Over time, an understanding emerged and today we have a solid scientific understanding of how water impacts on product quality and safety. We now know

that the water content is less important than the specific behaviour of the water or Water Activity. Water activity is related to water content in a non-linear relationship which is represented using as a moisture sorption isotherm curve. So while there can be a correlation between Water Activity and Total Moisture it is more critical for food safety to know the Water Activity. However for processing it can be equally critical to know the Total moisture.

Water Activity (Aw)

This is the most important parameter of water in terms of food safety. Water activity or Aw is the partial vapor pressure of water in a substance divided by the standard state partial vapor pressure of water. In the field of food science, the standard state is most often defined as the partial vapor pressure of pure water at the same temperature. Using this particular definition, pure distilled water has a water activity of exactly one. To understand this more fully, we must recognise that much of the water in food is bound water, i.e. bound to ions as water of hydration, or bound to surfaces of large molecule or cell structures. This water is not free to support microbial growth, or to participate in or support chemical or enzyme reactions and spoilage processes. The "Total" amount of bound water in a food has little relation to food stability.
The free or available water in a food supports microbial growth, and participates in and supports chemical and enzymatic reactions and spoilage processes. It is this amount of free water which is called water activity, Aw and it is more important for food stability, chemical and microbial, than total water content.
The factors that reduce the mobility of water in a food also reduce its tendency to evaporate and its vapour pressure and this provides a means of defining and measuring it.

Food	**% Water**	**Food**	**% Water**
Lettuce, tomatoes	95	Cabbage, broccoli	92
Carrots, potatoes	90	Citrus fruit	87
Apples, cherries	85	Raw poultry	72
Raw lean meat	60	Cheese	37
White bread	35	Salami	30
Preserves	28	Honey	20

Dried fruit	18	Butter	18
Wheat flour	12	Dried pasta	12
Milk powder	4	Beer	90
Fruit juices	87	Milk	87

Therefore, we can generally define Water Activity (Aw) as an indication of the amount of Free Water in a food.

Specifically Water Activity (Aw) is:
= Actual Equilibrium V.P. of air-space over the food Equilibrium V.P of pure water at same temperature
Alternatively we can define it using Relative Humidity (RH):
= Actual V.P. water vapour in air x 100 Equilibrium V.P. of Pure Water at Same Temperature
Water Activity
= Relative Humidity of Airspace Over the Food / 100
The ideal solution may be written as:
Aw = P = %ERH Po 100

Effects of Reduced Aw on Food Safety

The rates of certain chemical and biochemical processes are affected by the amount of available water. One of the effects of reducing the Aw in a food product is to reduce the rate of these reactions. The exception is the oxidation of fats where the rate decreases down to 0.4 to 0.5, then increases. Another chemical reaction effect is Maillard Browning which is maximized at 0.6-0.7. Most enzymes are inactivated at <0.85. At less than 0.75 bacterial growth is inhibited but some yeast and moulds may grow. At less than 0.6 all growth is inhibited. In terms of nutrients, reduced Aw reduces losses of Vitamins C, E, B1. The following table indicates the Aw of certain foods.

Food Typical Aw

Fresh meat 0.98
Cheese 0.97
Preserves 0.88
Salami 0.83
Dried fruit 0.76
Honey 0.75
Pasta 0.50

In general, bacteria require higher values of Aw for growth than fungi, with gram-negative bacteria having higher requirements than gram-positive.

Minimum Aw values for growth of microorganism groups in food

Most spoilage bacteria 0.90
Most spoilage yeasts 0.88
Most spoilage moulds 0.80
Halophilic bacteria 0.75
Xerophilic moulds 0.61
Osmophilic yeasts 0.61

Minimum Aw values for growth of specific microorganisms in food

Candida scottii 0.92
Pseudomonas spp. 0.97
Trichosporon pullulans 0.91
Acinetobacter spp. 0.96
Candida zaylanoides 0.90
Escherichia coli 0.96
Staphylococcus aureus 0.86
Enterobacter aerogenes 0.95

Bacillus subtilis 0.95
Penicillium patulum 0.81
Clostridium botulinum, types A and B 0.94
Aspergillus conicus 0.70
Candida utilis 0.94
Aspergillus echinulatus 0.64
Vibro parahaemolyticus 0.94
Zygosaccharomyces rouxii 0.62
Botrytis stolonifer 0.93
Rhizopus stolonifer 0.93

Reducing Aw

Reducing the Aw of a food product may be achieved through a number of methods. The most obvious is by partial removal of water in the food product using a variety of methods.
Alternately the concentration of water can also be reduced by the addition of other substances
Such as salt and sugar.

Relationship between Water Activity and TOTAL Water

There is often confusion between water activity and water content (Total) measurements. In many sectors, water content is used to control the amount of water present in a product for quantitative reasons.
For example, where a product is sold by weight, controlling its TOTAL water content may be important to meet legal and commercial requirements. Also if you are preparing products for cooking or baking knowing the Total Moisture may be initially critical. Water activity is more significant for qualitative considerations such as product stability, shelf life (e.g. microbiological & enzymatic stability, aroma retention), handling characteristics, physical properties and chemical stability. Water activity and water content can be related by a graph called a Sorption Isotherm. We can plot such curves into our meters specific to certain products (please call us for more details here) to allow you to measure both parameters, the relationship can be defined and each parameter derived from the other (interpolation). In practice, the sorption isotherm may be impractical to use because, not only does the relationship between Aw and moisture content change with temperature of measurement, but also any variations in the material composition has a modifying effect.
You should therefore decide which parameter of measurement is best suited to your products and processes. For quality control purposes, moisture content limits are easily converted to water activity limits by very simple comparative tests. Water activity measurement offers a non- destructive, easy-to-use measurement in a wide range of convenient configurations for both laboratory and on-site use.

Analysis of Water Content

Gravimetric Method

Water content may be measured in food using a number of methods. The most basic of these are gravimetric methods. This involves drying a known quantity of the food product in an oven until all moisture has been evaporated. By measuring the dry matter content remaining, the water content can be determined. A vacuum oven can be used for heat sensitive foods. These methods are used by Schaller to generate custom calibration curves for our excellent range of Total Moisture Analyzers but are extremely laborious and time consuming for day to day use.

Analysis of Water Activity

Capacitance hygrometers

Capacitance hygrometers consist of two charged plates separated by a dielectric polymer membrane. As the membrane adsorbs water, its ability to hold a charge increases and the capacitance is measured. This value is roughly proportional to the water activity as determined by a sensor-specific calibration. Capacitance hygrometers are not affected by most volatile chemicals and can be much smaller than other alternative sensors. They should have regular calibration checks and can be affected by residual water in the polymer membrane (hysteresis).

Dew point /Chilled mirror hygrometers

The temperature at which dew forms on a clean surface is directly related to the vapor pressure of the air. Dew point hygrometers work by placing a mirror over a closed sample chamber.

The mirror is cooled until the dew point temperature is measured by means of an optical sensor. This temperature is then used to find the relative humidity of the chamber using psychrometric charts. This method is **theoretically** the most accurate (+/- 0.003 Aw) the sensors however require frequent cleaning to remove vapours that deposit on the mirrors and seriously affect the calibration. Furthermore they use small samples that affect the repeatability and are highly sensitive to small temperature variances that more than offset the theoretical accuracy.

Water Activity as a CCP

Water activity is frequently used as a critical control point for Hazard Analysis and Critical Control Points (HACCP) programs. Samples of the food product can be tested to ensure water activity values are within a specified range for food quality and safety.

Measurements can be made in as little as five minutes but one must be aware the FAST 5 minute modes reduce accuracy to less than 0.015 AW. It may be a legal requirement e.g. FDA/CFIA Regulations. However, it is important to know that lowering of the water activity of a food product is not in itself a lethal kill step since some pathogens can survive. Where it is used as a CCP or a specific control point it should be based on full validation of the product and process with clear limits.