Water activity in general

Water activity:

Water activity ($a_w$) or equilibrium relative humidity (ERH) measures the water vapour pressure generated by the water present in a hygroscopic product.

Water activity is based on a scale from 0 to 1.

The formulas:

$$a_w = \frac{p}{ps}$$

($p$ is the water vapour pressure above the product surface and $ps$ the water vapour pressure above the surface of pure water at the product temperature)

$$ERH = 100 \times a_w$$

Moisture content:

Water activity is often confused with moisture content. The moisture content of a product is usually defined as the percent weight of water content in relation to the dry weight of the sample.

Sorption isotherm:

At equilibrium, the relation between the percentage of water and the water activity of a hygroscopic material can be graphically represented by a curve: the sorption isotherm. For each $a_w$ value, the sorption isotherm shows the corresponding moisture content at a given constant temperature. Each product has its own sorption isotherm.

Water migration:

The $a_w$ of a product will always try to reach equilibrium with the surrounding atmosphere. Water will migrate from regions with a high $a_w$ to the regions of low $a_w$. Water will migrate until equilibrium is reached!

The effect of water in foodstuffs:

Water is also recognised in the food industry as being critical for the stability of most products. $a_w$ exerts a decisive influence on such phenomena as change in colour, taste and aroma, food poisoning and spoilage (shelf life), loss of vitamins...

Controlling the water activity of a product:

Water activity control is also an important factor for the chemical stability of foods. Most foodstuffs contain carbohydrates and proteins and are therefore subject to non-enzymatic browning reactions (Maillard reaction). The Maillard reaction gets stronger at increasing $a_w$ values and reached its peak at $a_w = 0.6...0.7$ with further increase of $a_w$ this reaction gets rapidly weaker.

Facts & figures:

A change in $a_w$ of a product can change the shelf life from a couple of days to a couple of weeks!

Pure distilled water has a water activity of exactly 1.

Salmonella bacteria can survive several weeks in a dry environment.

An example of a sorption isotherm:
Why the need to measure water activity?

Water migration

Late for work one morning, Paul forgets to put the lid back onto his cereals. When coming home later that evening, Paul finds that his cereals are all soft and no longer crunchy...

Most breakfast cereals lose their crunchiness with a $a_w > 0.4$. In this case the relative humidity of the air in Paul’s kitchen was above 40% rh and the water has migrated from the air (with a high level of relative humidity) to the cereals (with a low $a_w$ level).

In the food industry, there are two main cases where water migration could cause issues:

The first case would be when the finished product contains different components, each at a different $a_w$ level.

It is important that the $a_w$ is measured and not the moisture content as the moisture content will not help with water migration issues.

If we use the example of a cheese cake, the cheese has a $a_w = 0.95$ whereas the biscuit base has a $a_w = 0.3$. The water would migrate from the cheese to the biscuit, leaving you with a soggy base and a dried out cheese.

One solution would be to add humectants (sugar, salt, polymeric polyols…). The humectants will lower the $a_w$ level but not the moisture content!

Depending on the product it is also possible to lower the $a_w$ level by dehydrating and freezing.

The second issue would be the storage of the finished product and the atmosphere in which it is stored. Depending on the $a_w$ of the product and the relative humidity in the atmosphere, water migration could occur.

The main solutions to avoid water migration in this case, is to use a non-hygroscopic packaging or favourable storage conditions.

Water activity and micro-organisms

As mentioned previously, $a_w$ indicates the amount of water in the total water content which is available to micro-organisms.

Each micro-organism has its own minimum $a_w$ value below which, growth is no longer possible (growth is no longer possible but this doesn’t mean that the micro-organisms are not present).

By measuring the $a_w$ of food stuffs it is possible to determine which micro-organisms will be able to develop.

The US Food and Drug Administration (FDA) has adopted the concept of $a_w$ for establishing moisture limits beyond which certain types of food are considered susceptible to invasion by mould and bacteria. (Please see tables on page 4 for more information).

Often, $a_w$ is described as the amount of “free” water in a product and the moisture content, the amount of “bound” water in a product. Even though this is not a scientific description of $a_w$, it is easy to understand that chemically bound water is not accessible to

<table>
<thead>
<tr>
<th>$a_w$</th>
<th>Micro organisms generally inhibited by $a_w$ at this point</th>
<th>Examples of foods within this range of water activity.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.950</td>
<td>Pseudomonas, Escherichia, Proteus, Shigella, Klebsiella, Bacillus, Clostridium perfringens, some yeast.</td>
<td>Highly perishable foods (fresh and canned fruits, vegetables, meat, fish) and milk; cooked sausages and breads; foods containing up to 4oz (w/w) sucrose or 7%NaCl…</td>
</tr>
<tr>
<td>0.910</td>
<td>Salmonella, Vibrio parahaemolyticus, C. botulinum, Serratia, Lactobacillus, Pedicoccus, some molds, Rhodotorula, Pichia.</td>
<td>Some cheese (Cheddar, Swiss, Muenster, Provolone); cured meat (ham); some fruit juice concentrates; foods containing 55% (w/w) sucrose or 12%NaCl…</td>
</tr>
<tr>
<td>0.870</td>
<td>Many yeasts (Candida, Torulopsis, Hansenula), Micrococcus.</td>
<td>Fermented sausage (salami); sponge cakes; dry cheese; margarine; foods containing 65% (w/w) sucrose (saturated) or 15%NaCl…</td>
</tr>
<tr>
<td>0.800</td>
<td>Most molds (mycoctoxicogenic penicillia), Staphylococcus aureus, most Saccharomyces (bailli) spp., Debaryomyces.</td>
<td>Most fruit juice concentrates; sweetened condensed milk; chocolate syrup; maple and fruit syrups; flour; rice; pulses containing 15-17% moisture; fruit cake; country style ham; fondants; high-sugar cakes…</td>
</tr>
<tr>
<td>0.750</td>
<td>Most halophilic bacteria, mycoctoxicogenic aspergilla.</td>
<td>Jam, marmalade; marzipan; glazed fruits; some marshmallows…</td>
</tr>
<tr>
<td>0.650</td>
<td>Xerophilic molds (aspergillus chevalieri, A. Candidus, Walleria sebi), Saccharomyces bisporus.</td>
<td>Rolled oats containing ~10% moisture; grained rougais; fudge marshmallows; jelly; molasses; raw cane sugar; some dried fruits; nuts</td>
</tr>
<tr>
<td>0.600</td>
<td>Osmophilic yeasts (Saccharomyces rouxii), few molds (Aspergillus eichinulatus, Monascus bisporus).</td>
<td>Dried fruits containing 15-20% moisture; some toffees and caramels; honey…</td>
</tr>
<tr>
<td>0.500</td>
<td>No microbial proliferation</td>
<td>Noodles, spaghetti, etc containing ~12% moisture; spices containing ~10% moisture…</td>
</tr>
<tr>
<td>0.300</td>
<td>Cookies, crackers, bread crusts, etc. containing 3-5% moisture…</td>
<td></td>
</tr>
<tr>
<td>0.030</td>
<td>Whole milk powder containing 2-3% moisture; dried vegetables containing ~5% moisture; corn flakes containing ~5% moisture; dehydrated soups; some cookies and crackers…</td>
<td></td>
</tr>
</tbody>
</table>
What solutions can Rotronic offer?

Water activity or equilibrium relative humidity is usually defined as the percent relative humidity generated in equilibrium with the product sample in a closed system at constant temperature.

\[ ERH = 100 \times a_w \]

Therefore, \( a_w \) can be measured with a relative humidity sensor provided that the conditions specified in the above definition are fulfilled.

**Practical conditions for measuring water activity:**

- **Leak proof measurement chamber:** closed system.
- **Volume ratio:** air/product. The volume of air must be kept to a minimum: a small air volume reaches equilibrium with the sample faster than a large air volume.
- **Temperature homogeneity:** any temperature difference between the sensor, the chamber and the sample will result in significant errors. The higher the \( a_w \) value the greater the error will be (a 0.8\( a_w \) at 25°C with a 1°C temperature difference can result in an error of 0.05\( a_w \)).
- **Constant temperature needs to be kept.**
- **Equilibrium time:** in order to read the correct water activity value, equilibrium needs to be reached! The higher the \( a_w \) the longer it takes!
- ** Calibration of the sensor:** using traceable humidity standards.

Rotronic offers a complete \( a_w \) measurement product range!

**Rotronic products:**

**Humidity and temperature probes:**

- **HC2-AW**
  - 5...50°C,
  - 0...1\( a_w \),
  - Large thermal mass,
  - ±0.008\( a_w \) and ±0.1K...

- **HC2-AW-USB**
  - Same as HC2-AW but with direct connection to PC.

- **HC2-P05**
  - Insertion probe,
  - -40...85°C,
  - 0...1\( a_w \),
  - Ø5mm x 200mm,
  - ±0.015\( a_w \) and ±0.3K...

- **HC2-HP28**
- **HC2-HP50**
  - Insertion probe,
  - 40...85°C,
  - 0...1\( a_w \),
  - Ø10mm x 280 or 500mm,
  - ±0.008\( a_w \) and ±0.1K...

**Laboratory display units:**

- **HygroLab C1**
  - 4 probe connections,
  - Data logging,
  - Display,
  - Ethernet & USB connection,
  - AwE and AwQuick,
  - Buzzer...

- **HP23-AW-A**
  - Hand held device,
  - 2 probe connections,
  - Data logging,
  - Display,
  - AwE & AwQuick
  - Buzzer...

**Accessories:**

- **Sample holders**
  - WP-14-S, 14mm depth,
  - WP-40, 40mm depth.

- **Disposable sample containers**
  - PS-14, containers for WP-14-S,
  - PS-40, containers for WP-40

- **Clamp sealing mechanism:**
  - AW-KHS, sealing clamp

- **SCS humidity standards**
  - EAxx-SCS, unsaturated salt solutions,
  - Different humidity values available: 0, 5, 10, 11, 20, 35, 50, 60, 65, 75, 80 and 95%...

**Water activity sets:**

Various sets are available, please contact us for more details.

**What can Rotronic offer?**

**Water activity or equilibrium**

relative humidity is usually defined as the percent relative humidity generated in equilibrium with the product sample in a closed system at constant temperature.

**Equilibrium time:** in order to read the correct water activity value, equilibrium needs to be reached! The higher the \( a_w \) the longer it takes!

**Calibration of the sensor:** using traceable humidity standards.

Rotronic offers a complete \( a_w \) measurement product range!
How Rotronic measures water activity:

With the Rotronic product range, there are two different ways to measure water activity: AwE and AwQuick.

**AwE mode:** the natural equilibration of the product is measured and the measurement process is automatically stopped once equilibrium is reached. With most products, natural equilibrium requires from 45 to 90 minutes.

**AwQuick mode:** this mode reduces the time required to measure water activity to a few minutes, usually with almost the same accuracy as the AwE mode.

Water activity measurement reports:

Combined with the Rotronic HW4 software, it is possible to automatically generate a report as soon as the measurement is finished.

Rotronic water activity sets:

Rotronic offers different sets, offering a complete solution for everyone needing to measure water activity. The sets often contain, a display units, a aw measurement device, a sample holder and disposable containers as well as Rotronic humidity standards for the calibration of the measurement device.

**Accuracy and long term stability:**
Choosing Rotronic gives you the best accuracy on the market.

This helps carry out fast and effective water activity measurements on all foodstuffs.

With a long term stability of under 0.001 aw, the measurement devices will not need much taking care of! This being said, we would recommend frequent spot checks in-between calibrations.

**Calibration and adjustment:**
Calibration and adjustment is very easy with the Rotronic product range. As all of the communication is digital, the whole calibration procedure can be done via a PC, or directly from the display unit (HP23-AW-A or the HygroLab C1) with the help of the Rotronic humidity standards. Rotronic can also offer a factory calibration (certified or not).

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### Table A. Interaction of pH and aw for control of spores in food heat-treated to destroy vegetative cells and subsequently packaged

<table>
<thead>
<tr>
<th>aw values</th>
<th>pH values</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤0.92</td>
<td>non-PHF / non-TCS Food**</td>
</tr>
<tr>
<td>&gt; 0.92 - 95</td>
<td>non-PHF / non-TCS Food**</td>
</tr>
<tr>
<td>&gt; 0.95</td>
<td>non-PHF / non-TCS Food</td>
</tr>
</tbody>
</table>

* PHF means POTENTIALLY HAZARDOUS FOOD
** TCS Food means Time/Temperature Control for Safety Food
*** PA means Product Assessment required

### Table B. Interaction of pH and aw for control of vegetative cells and spores in food not heat-treated or heat-treated but not packaged

<table>
<thead>
<tr>
<th>aw values</th>
<th>pH values</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.88</td>
<td>non-PHF / non-TCS Food</td>
</tr>
<tr>
<td>0.88 – 0.90</td>
<td>non-PHF / non-TCS Food</td>
</tr>
<tr>
<td>&gt; 0.90 – 0.92</td>
<td>non-PHF / non-TCS Food</td>
</tr>
<tr>
<td>&gt; 0.92</td>
<td>non-PHF / non-TCS Food</td>
</tr>
</tbody>
</table>

* PHF means POTENTIALLY HAZARDOUS FOOD
** TCS Food means Time/Temperature Control for Safety Food
*** PA means Product Assessment required

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Customer benefits:

**FDA Food code 2005: Potentially hazardous food**

![Rotronic HW4 Software](image)
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Rotronic is represented in over 40 countries around the world. An up to date list of all our partners is available on our website: www.rotronic.com

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