

## Water activity in the food industry



Cheese cake

### 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.

### 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 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...

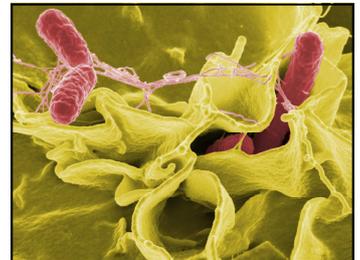
#### Controlling the water activity of a product:

The  $a_w$  in foods can be controlled by using various additives (humectants), by using satisfactory packaging materi-

als, by maintaining favourable maturation and storage conditions...

#### Water activity and micro-organisms:

Water activity also indicates the amount of water which is available to micro organisms. Each species of micro organism (bacteria, yeast, mould) has a minimum  $a_w$  value below which, growth is no longer possible.

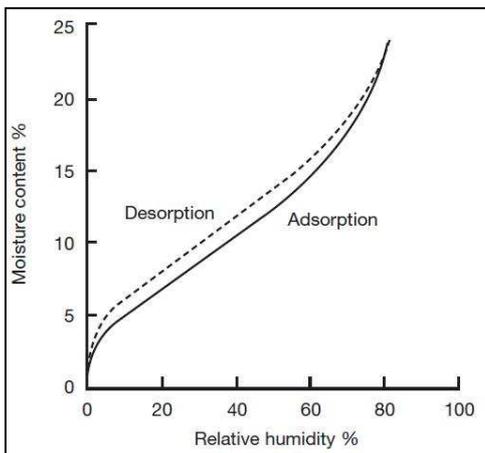


Salmonella

#### Chemical stability:

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.

#### An example of a sorption isotherm:



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

#### The formulas:

$$a_w = p / p_s$$

( $p$  is the water vapour pressure above the product surface and  $p_s$  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

#### Discussed in this edition:

- Water activity in general **1**
- Why the need to measure water activity? **2**
- Water migration **2**
- Water activity and micro-organisms **2**
- What solution can Rotronic offer? **3**
- Rotronic Products **3**
- Customer benefits **4**
- Contact us **5**

## Why the need to measure water activity?



Breakfast cereal

### 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 humec-

tants 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.



Stay fresh packaging

**store in a cool dry place**

Storage guidelines

## 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 micro-organisms, whereas free water is.

$a_w$	Micro organisms generally inhibited by $a_w$ at this point	Examples of foods within this range of water activity.
0.950	Pseudomonas, Escherichia, Proteus, Shigella, Klebsiella, Bacillus, Clostridium perfringens, some yeast.	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...
0.910	Salmonella, Vibrio parahaemolyticus, C. botulinum, Serratia, Lactobacillus, Pediococcus, some molds, Rhodotomula, Pichia.	Some cheese (Cheddar, Swiss, Muenster, Provolone); cured meat (ham); some fruit juice concentrates; foods containing 55%(w/w) sucrose or 12%NaCl...
0.870	Many yeasts (Candida, Torulopsis, Hansenula), Micrococcus.	Fermented sausage (salami); sponge cakes; dry cheese; margarine; foods containing 65% (w/w) sucrose (saturated) or 15%NaCl...
0.800	Most molds (mycotoxigenic penicillia), Staphylococcus aureus, most Saccharomyces (baillii) spp., Debaryomyces.	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...
0.750	Most halophilic bacteria, mycotoxigenic aspergilla.	Jam, marmalade; marzipan; glazed fruits; some marshmallows...
0.650	Xerophilic molds (aspergillus chevalieri, A. Candidus, Wallemia sebi), Saccharomyces bisporus	Rolled oats containing ~10% moisture; grained nougats; fudge marshmallows; jelly; molasses; raw cane sugar; some dried fruits; nuts
0.600	Osmophilic yeasts (Saccharomyces rouxii), few molds (Aspergillus echinulatus, Monascus bisporus)	Dried fruits containing 15-20% moisture; some toffees and caramels; honey...
0.500	No microbial proliferation	Noodles, spaghetti, etc. containing ~12% moisture; spices containing ~10% moisture...
0.300		Cookies, crackers, bread crusts, etc. containing 3-5% moisture...
0.030		Whole milk powder containing 2-3% moisture; dried vegetables containing ~5% moisture; corn flakes containing ~5% moisture; dehydrated soups; some cookies and crackers...

Source: Water activity and Microbial stability, L.R. Beuchat.

## 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

$0.8a_w$  at 25°C with a 1°C temperature difference can result in an error of  $0.05a_w$ ).

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!*



HP23-AW-A with the HC2-AW and HC2-P05



HygroLab C1

## Rotronic products:

### Humidity and temperature probes:

- **HC2-AW**  
5...50°C,  
0...1 $a_w$ ,  
Large thermal mass,  
 $\pm 0.008a_w$  and  $\pm 0.1K$ ...
- **HC2-AW-USB**  
Same as HC2-AW but with direct connection to PC.
- **HC2-P05**  
Insertion probe,  
-40...85°C,  
0...1 $a_w$ ,  
 $\varnothing 5mm \times 200mm$ ,  
 $\pm 0.015a_w$  and  $\pm 0.3K$ ...
- **HC2-HP28**
- **HC2-HP50**  
Insertion probe,  
40...85°C,  
0...1 $a_w$ ,  
 $\varnothing 10mm \times 280$  or  $500mm$ ,  
 $\pm 0.008a_w$  and  $\pm 0.1K$ ...

### 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%...



WP-14-S



AW1-SET-40



AW-KHS sealing clamp



HC2-P05



HC2-HP28 or HC2-HP50



WP-14-S

# rotronic

LEADING IN HUMIDITY MEASUREMENT

## Customer benefits:

### 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  $a_w$  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 $a_w$ , the measurement devices will not need much taking care off! 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).

Table A. Interaction of pH and  $A_w$  for control of spores in FOOD heat-treated to destroy vegetative cells and subsequently PACKAGED

$A_w$ values	pH values		
	4.6 or less	> 4.6 - 5.6	> 5.6
≤ 0.92	non-PHF*/non-TCS FOOD**	non-PHF/non-TCS FOOD	non-PHF/non-TCS FOOD
> 0.92 - .95	non-PHF/non-TCS FOOD	non-PHF/non-TCS FOOD	PA***
> 0.95	non-PHF/non-TCS FOOD	PA	PA

\* 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  $A_w$  for control of vegetative cells and spores in FOOD not heat-treated or heat-treated but not PACKAGED

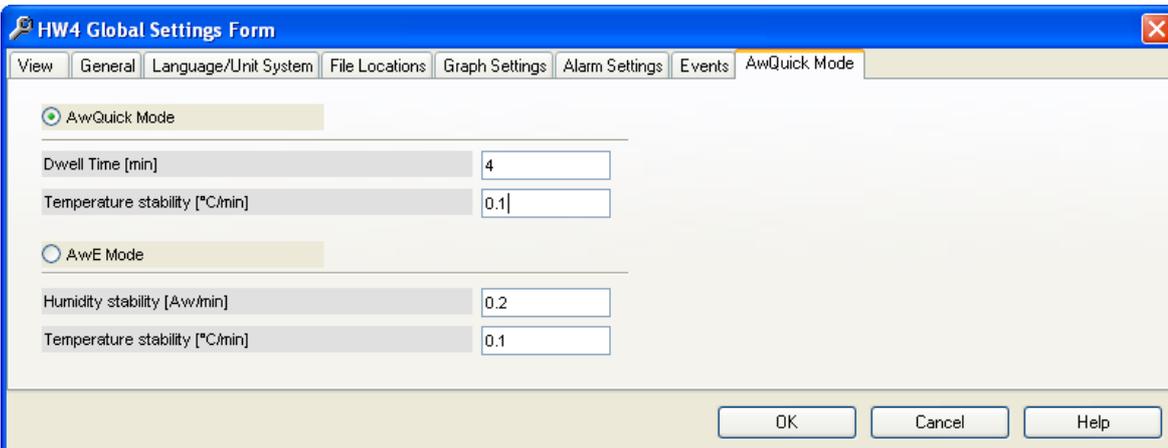
$A_w$ values	pH values			
	< 4.2	4.2 - 4.6	> 4.6 - 5.0	> 5.0
< 0.88	non-PHF*/non-TCS food**	non-PHF/non-TCS food	non-PHF/non-TCS food	non-PHF/non-TCS food
0.88 – 0.90	non-PHF/non-TCS food	non-PHF/non-TCS food	non-PHF/non-TCS food	PA***
> 0.90 – 0.92	non-PHF/non-TCS food	non-PHF/non-TCS food	PA	PA
> 0.92	non-PHF/non-TCS food	PA	PA	PA

\* PHF means POTENTIALLY HAZARDOUS FOOD  
 \*\* TCS FOOD means TIME/TEMPERATURE CONTROL FOR SAFETY FOOD  
 \*\*\* PA means Product Assessment required

FDA Food code 2005: Potentially hazardous food

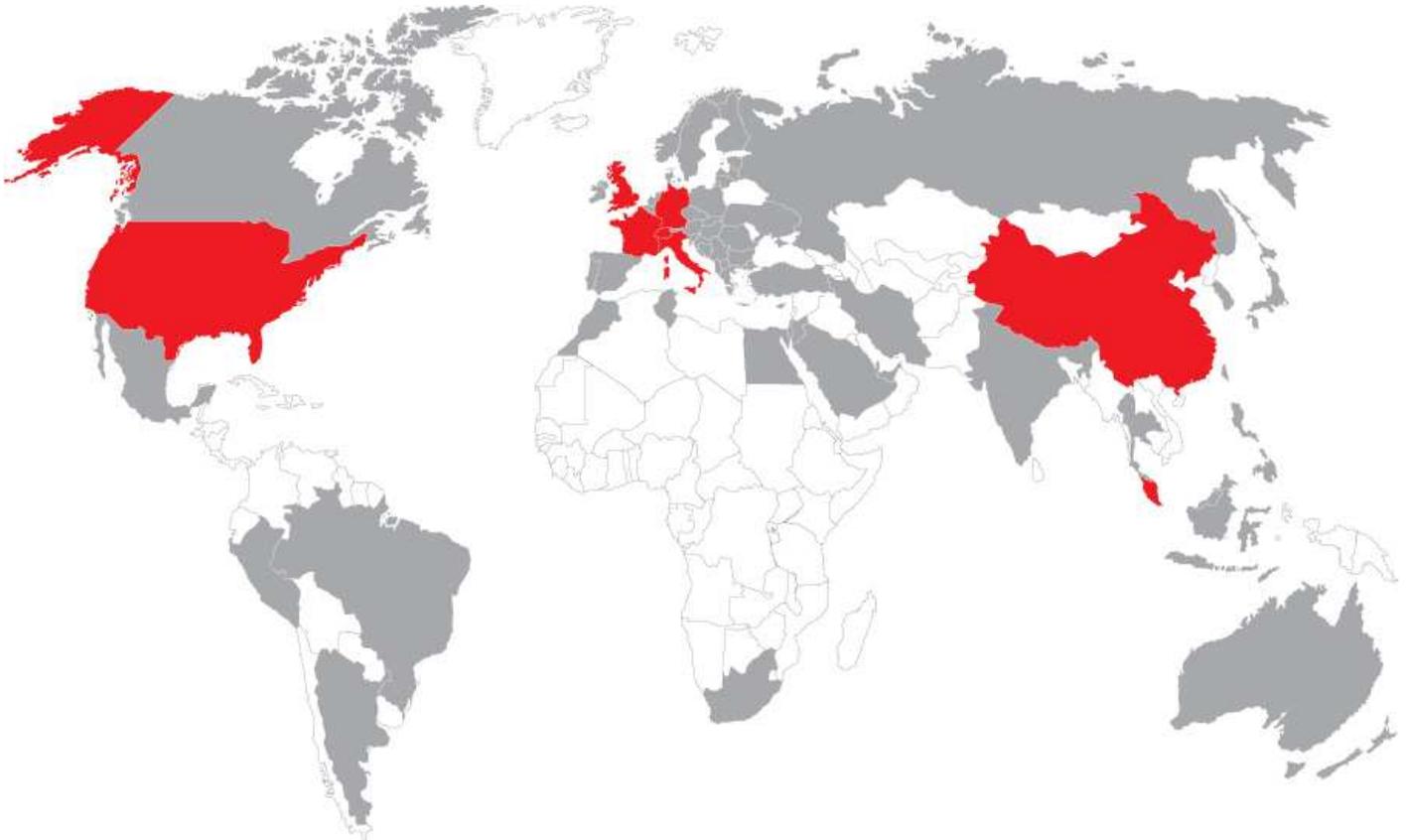


Rotronic HW4 Software



## Contact us:

Rotronic is represented in more than 40 countries around the world. An up to date list of all our partners is available at [www.rotronic-humidity.com/international](http://www.rotronic-humidity.com/international)



### SWITZERLAND

#### **ROTRONIC AG**

Grindelstrasse 6,  
CH-8303 Bassersdorf  
Phone: +41 44 838 11 44  
Fax: +41 44 837 00 73  
[www.rotronic-humidity.com](http://www.rotronic-humidity.com)

### FRANCE

#### **ROTRONIC Sarl**

56, Bld. De Courcerin,  
F-77183 Croissy-Beaubourg.  
Phone: +33 1 60 95 07 10  
Fax: +33 1 60 17 12 56  
[www.rotronic.fr](http://www.rotronic.fr)

### SINGAPORE

#### **ROTRONIC South East Asia Pte Ltd**

16 Kallang Place #07-04  
Singapore 339156  
Phone: +65 6294 6065  
Fax: +65 6294 6096  
[www.rotronic.com.sg](http://www.rotronic.com.sg)

### GERMANY

#### **ROTRONIC Messgeräte GmbH**

Einsteinstrasse 17-23  
DE-76275 Ettlingen  
Phone: +49 7243 383 250  
Fax: +49 7243 383 260  
[www.rotronic.de](http://www.rotronic.de)

### UK

#### **ROTRONIC Instruments UK Ltd.**

Crompton Fields, Crompton Way  
Crawley, West Sussex, RH10 9EE  
Phone: +44 1293 57 10 00  
Fax: +44 1293 57 10 08  
[www.rotronic.co.uk](http://www.rotronic.co.uk)

### ITALY

#### **ROTRONIC Italia srl**

Via Repubblica di San Marino, 1  
I-20157 Milano (MI)  
Phone: +39 02 39 00 71 90  
Fax: +39 02 33 27 62 99  
[www.rotronic.it](http://www.rotronic.it)

### USA

#### **ROTRONIC Instrument Corp.**

Suite 150, 135 Engineers Road, Haupt-  
pauge, NY 11788  
Phone: +1 631 427 38 98  
Fax: +1 631 427 39 02  
[www.rotronic-usa.com](http://www.rotronic-usa.com)

### CHINA

#### **ROTRONIC Shanghai Rep. Office**

2B, Zao Fong Universe Building, No. 1800  
Zhing  
Shan West Road, Shanghai 200233  
China  
Phone: +86 21 644 03 55  
Fax: +86 21 644 03 77  
[www.rotronic-humidity.cn](http://www.rotronic-humidity.cn)