FOCUS

Water

Water Activity in aquafeed:

Safety, Quality, and Profitability

By Brady Carter, PhD, Decagon Devices

Many aquafeed manufacturers measure water activity to prevent mold during storage. By assuming that water activity is only about microbes and mold, they miss the opportunity to use this versatile measurement to improve quality and profitability, too.

Over-processing Causes Losses

Mold is one of the most common reasons that an aquafeed product is ruined during storage. Because a product is safe from mold at 0.65aw, a manufacturer may mistakenly assume that a lower water activity is better because it is "even safer." However, there is no gain in safety or shelf-life by drying to water activities lower than 0.65aw, because the growth of all pathogenic bacteria is limited at 0.86aw and mold growth is stopped at 0.65aw. In fact, over-drying can result in lost quality and profit.

An over dried aquafeed product may have pelletization problems and other texture-related issues. In a product that is sold on a per weight basis, over-drying also directly impacts profitability. Those producers who understand the safety and quality implications of water activity will produce aquafeed at a “sweet spot” slightly below the critical 0.65aw value, maximizing safety, quality, and profitability.

Moisture Analysis

The relationship between water activity and microbial growth makes water activity a powerful safety specification. While moisture content can be an important standard of identity, the USDA explains that it is “not a safety consideration.” The best measure of safety is water activity. But why?

Molds and microorganisms like Listeria and Salmonella need water to grow and reproduce. They take in water through the cell membrane that surrounds them. The power to move that water into the cell comes from energy differences between the water outside the cell and the water inside the cell.

Water moves on a gradient from high to low energy. Picture a pot of boiling water. The energy of the water molecules in the pot is higher than the energy of the water molecules in the atmosphere, and you can imagine the water becoming steam and moving from the pot to the atmosphere.

In fact, water is always moving. A bag of aquafeed in a moist environment might take up water. In a dry environment, it might lose water.

Water activity is a way of measuring the energy of water in a sample in order to accurately predict how water molecules will move, or whether they will be available for use by mold and microorganisms. It is measured on a scale from 0 to 1.0, where 1.0 represents the energy of pure water.

Mold and Microbial Growth

The water activity concept has served microbiologists and food technologists for decades and is the most commonly used criterion for food safety and quality. Microorganisms and mold have a limiting water activity below which they cannot grow (Beuchat, 1983;Scott, 1957). Water activity, not moisture content, determines the lower limit of "available" water for microbial growth.

Table 1 shows the growth limit for the common spoilage organisms. These values were established in environments where all other conditions (eg., pH and temperature) were ideal for microbial growth. They represent the true lower water activity where no other factors limit growth. The water activity level that limits the growth of the vast majority of pathogenic bacteria is 0.90. A water activity of 0.70 is the lower limit for spoilage molds, and the limit for all microorganisms is 0.60.

Drying aquafeed below a critical aw level will control mold and microbial growth. Water may be present, even at higher content levels than normally acceptable in aquafeed, but if water activity is sufficiently low, microorganisms cannot utilize the water to support their growth.

In this 'desert-like' condition, there is an osmotic imbalance between the microorganisms and the local environment, and the microbes will become dormant or die. Table 2 shows a survey of the water

Table 1. Water activity lower limit for growth for common spoilage organisms.

Microorganism	Minimum a_w	Microorganism	Minimum a_w
Clostridium botulinum E	0.97	*Penicillum expansum*	0.83
Pseudomonas fluorescens	0.97	*Penicillum islandicum*	0.83
Escherichia coli	0.95	*Debarymoces hansenii*	0.83
Clostridium perfringens	0.95	*Aspergillus fumigatus*	0.82
Salmonella spp.	0.95	*Penicillum cyclopium*	0.81
Clostridium botulinum A, B	0.94	*Saccharomyces bailii*	0.80
Vibrio parahaemoliticus	0.94	*Penicillum martensii* *Penicillum chrysogenum*	0.79
Bacillus cereus	0.93	*Aspergillus niger*	0.77
Rhizopus nigricans	0.93	*Aspergillus ochraceous*	0.77
Listeria monocytogenes	0.92	*Aspergillus restrictus*	0.75
Bacillus subtilis	0.91	*Aspergillus candidus*	0.75
Staphylococcus aureus (anaerobic)	0.90	*Eurotium chevalieri*	0.71
Saccharomyces cerevisiae	0.90	*Eurotium amstelodami*	0.70
Candida	0.88	*Zygosaccharomyces rouxii*	0.62
Staphylococcus aureus (aerobic)	0.86	*Monascus bisporus*	0.61

(adapted from Beuchat 1983)

Table 2: Water activities of common aquafeed products as measured using Decagon Devices' AquaLab chilled mirror water activity instrument.

Product	Water Activity	% Maximum Moisture Content
Trout 450 3/32"	0.6287	8.8
Trout Grower #4	0.5047	6.2
Shrimp 35/2.5	0.5043	7.1
Shrimp Starter #1 40/5	0.4831	7.9
Catfish 5/32"	0.4733	7.1
Trout 450 3/16"	0.4495	6.2
Shrimp Starter #2 40/5	0.4343	6.9
Trout Starter #2	0.4314	6.2
Trout 400 1/8"	0.4188	6.1
Grower 400	0.4072	6.2
Steelhead 1/8"	0.3263	5.2
Fingerling 300	0.3154	5.0
Game Fish Chow	0.3137	5.0
Shrimp Production 3/32"	0.2757	4.2

*All samples except for Grower 400, Fingerling 300, and Game Fish Chow were generously provided by Rangen, Inc.

activity and moisture content of several different samples of aquafeed. These water activities were measured using an AquaLab chilled mirror water activity instrument (Decagon Devices, Inc). All tests were run in duplicate. These results indicate a range of water activity/ moisture content combinations depending on the formulation of the aquafeed product. A comparison of the values in Table 2 and Table 1 gives an indication of the susceptibility of these products to spoilage based on their water activity.

Comparing the two tables also illustrates why moisture content is not a good indicator of susceptibility to mold or microbial spoilage.

A higher moisture level can create better texture, improve manufacturing processes, and preserve profits. Water activity can be controlled during formulation by using humectants such as salt, sugar, propylene glycol, and glycerol.

Measurement of Water Activity

Aquafeed producers typically test water activity after pelleting, or on the fishmeal if it's going to be stored. To perform a test, the user places a small sample of the product in a sample cup, which is then sealed inside a testing chamber. When the water activity of the sample and the relative humidity of the air are in equilibrium, the measurement of the headspace humidity gives the water activity of the sample. Instruments determine the relative humidity of the headspace either directly, using a chilled mirror dewpoint sensor or a tuneable diode laser, or indirectly using a capacitance sensor. Direct methods are more accurate. The fastest methods take less than five minutes, and allow some manufacturers to perform at-line monitoring of a product's water activity. Portable instruments are also available, though they are typically less accurate.

Water Activity—A Moisture Super -Spec

Because water activity is an indicator of both safety and quality, it provides producers with a "moisture super-spec"--a measurement that allows them to produce a safe product without over-drying. It is a key specification for safety, quality, and profitability in aquafeeds.

References

Beuchat,L.R. 1983. Influence of water activity on growth, metabolic activities, and survival of yeasts and molds. J Food Prot 46:135-141,150.

Brandt,L. 1996. Bound for success. Controlling water activity gives technologists the edge in developing safe, shelf-stable foods. Food Formulating 2:41-48.

Katz,E.E. and T.P.Labuza. 1981. Effect of water activity on the sensory crispness and mechanical deformation of snack food products. J Food Sci 46:403-409.

Lowe,J.A. and S.J.Kershaw. 1995. Water activity-moisture content relationship as a predictive indicator for control of spoilage in commercial pet diet components. Animal Feed Science and Technology 56:187-194.

Scott,W.J. 1957. Water relations of food spoilage microorganisms. Adv Food Res 7:83-127.

Bell,L.N., and T.P.Labuza. 2000. Moisture sorption: practical aspects of isotherm measurement and use. American Association of Cereal Chemists, St. Paul, MN.

Xin Yu. 2007. Investigation of moisture sorption properties of food materials using saturated salt solution and humidity generating techniques. Ph.D. thesis, University of Illinois at Urbana-Champaign.

" An over dried aquafeed product may have pelletization problems and other texture-related issues. In a product that is sold on a per weight basis, over-drying also directly impacts profitability."

More information

Dr. Brady Carter is the Senior Research Scientist for Aqualab at Decagon Devices.

E: brady@decagon.com.