K-STATE Research and Extension

Water Activity of Foods

MU Extension University of Missouri

Food Safety Fact Sheet

Understanding and controlling water activity levels are integral components of ensuring the quality and safety of food items as related to regulatory compliance and the overall preservation of various food products.

What is Water Activity?

Water activity (a_w) measures the amount of free water that is available in food for microorganisms to survive or grow. Water activity is defined as the ratio of water vapor pressure in food to that of pure water. Lower a_w means less available water for microbial growth. The a_w scale ranges from 0 to 1, with 0 indicating no available water and 1 representing pure water. Moisture content is different than a_w as it measures the total water present in a food product.

Understanding the water activity levels in food assists in extending shelf life, enhancing safety, and preserving the overall quality of foods. Figure 1 shows a water activity meter, which measures the a_w in food.

Testing Water Activity

The Kansas Value Added Food Labs at Kansas State University tests the water activity levels of food products. To get detailed information on costs and paper work refer to the link here: *https://www.ksre.k-state.edu/kvafl/fees-information.html*

The University of Minnesota has information on testing water activity in cottage foods using the Elitech GSP-6 meter and the Excel Correction tool. It has detailed information on ordering a testing kit, how the meter works, calibration, and measuring water activity. To access more information, refer to this link: *https://extension.umn.edu/food-entrepreneurs/testing-water-activity-cottage-foods*.

Effect of Water Activity on Microbial Growth

Microorganisms have specific a_w levels below which they cannot grow. It is not the moisture content but the water activity that determines the availability of water for microbial growth. Most bacteria that cause food spoilage need a minimum a_w of about 0.90 to grow. For instance, approximate minimum a_w for *Staphylococcus aureus* is 0.91 in anaerobic conditions and 0.86 in aerobic conditions. Molds and yeasts have a lower limit of about 0.61 a_w. Figure 2 shows how water activity levels affect microbial growth.

Water activity levels of common foods are listed below:

- Fresh meat and fish: 0.99
- Raw vegetables: 0.99

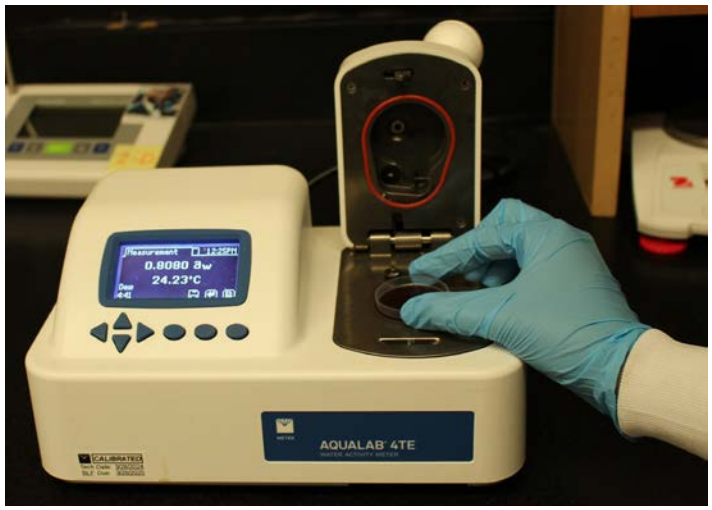

Figure 1. A water activity meter.

- Raw fruits: 0.98
- Jams, marmalades, jellies: 0.75-0.80
- Soy sauce: 0.8
- Peanut butter: 0.7

Table 1 on page 3 summarizes the minimum water activity limits for various microorganisms and examples of foods within these ranges. This table shows the water activity range where different microorganisms growth is inhibited and the foods in that range.

Use salt or sugar to bind available water to control water activity levels. In certain production scenarios, regular checks on water activity levels may not be needed. For example, if salt serves as the preservative, measuring salt percentage alone could suffice to ensure controlled water activity. However, it is essential for the processor or process

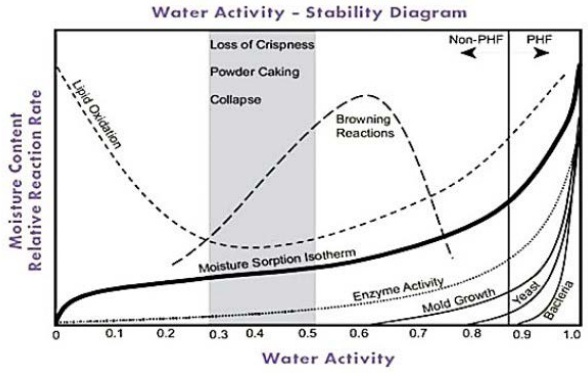

Figure 2. How water activity levels affect microbial growth and initiates certain chemical reactions like lipid oxidation and browning reactions. (Source: *https://www.chemijournal.com/archives/2019/vol7issue6/PartT/SP-7-6-225-417.pdf*)

authority to review consistent data linking salt levels in the product to water activity levels.

What is a Water Activity-Controlled Formulated Food Product?

A water activity-controlled formulated food product is one where the water activity (a_w) is managed to prevent microbial growth, ensuring safety, and extending shelf life. Ingredients like salt and sugar will bind water, thus reducing available water for microorganisms to grow or survive. For example, high sugar content in jams lowers water activity to inhibit microbial growth, and salt in meats has the same effect. However, there are several ways to reduce water activity as mentioned below.

Adding Salt: Salt helps preserve food, such as adding salt in soy sauce. The amount needed depends on the food's initial water activity, especially for low sodium soy sauces.

Adding Sugar: Sugar keeps candies and low-acid jams shelf-stable. The required amount depends on the food's starting water activity.

Adding Pectin: Pectin forms a gel network and traps the water so there is no available water for microorganisms to grow or survive. Pectin is used in jams and jellies to have a shelf-stable product.

Other Humectants: Ingredients like glucose syrup, sorbitol, dextrose, or glycerol reduce water activity by binding the available water without making food too salty or sweet and allowing them to be shelf-stable. Examples include intermediate moisture foods (IMF) such as dried fruits, jams, soft cookies, and semi-moist pet foods. IMF are shelf-stable foods that have a water activity of 0.6 to 0.84 and a moisture content of 15 to 40%.

Regulatory Significance

The U.S. Food and Drug Administration (U.S./FDA) utilizes water activity as a regulatory tool for certain food products. A water activity (a_w) level of 0.85 is the threshold used to determine if a low-acid canned food or an acidified food falls under regulatory guidelines.

A low-acid canned food (LACF) is any food (other than alcoholic beverages) with a finished equilibrium pH greater than 4.6 and a water activity greater than 0.85, excluding tomatoes and tomato products having a finished equilibrium pH less than 4.7.

Clostridium botulinum requires a minimum a_w level of around 0.93 to grow, and in some cases, this can be as high as 0.96, therefore it is critical to maintain pH below 4.6 and/or water activity below 0.85 to ensure the safety of food.

Regulations (21 CFR 113.3(e)(1)(ii)) specify that commercial sterility can be achieved by controlling water activity and applying heat. Heat is essential at a_w levels above 0.85 to eliminate vegetative cells of harmful microorganisms, such as staphylococci, and spoilage microorganisms that thrive in reduced water activity environments.

Various sections of the regulations address complementary aspects.

- 21 CFR 113.81(f) delves into additional factors for microbial control
- 21 CFR 113.100(a) (6) outlines record-keeping requirements for water activity determinations.

Food manufacturers and processors must monitor and control water activity to ensure product safety and quality. Compliance with water activity regulations is a fundamental aspect of food preservation practice.

References

1. FDA. Water activity (a_w) in foods. U.S. Food and Drug Administration. *https://www.fda.gov/inspections-compliance-enforcement-and-criminal-investigations/inspection-technical-guides/water-activity-aw-foods* Date accessed June 24, 2024.

2. Agriculture: Province of Manitoba. Water Content and Water Activity: Two Factors That Affect Food Safety. *https://www.gov.mb.ca/agriculture/food-safety/at-the-food-processor/water-content-water-activity.html* Date accessed June 24, 2024.

3. FDA. Acidified & low-acid canned foods guidance documents & regulatory information. *https://www.fda.gov/food/guidance-documents-regulatory-information-topic-food-and-dietary-supplements/acidified-low-acid-canned-foods-guidance-documents-regulatory-information* Date accessed July 7, 2024.

4. Virginia Cooperative Extension. Understanding the Water Activity of Your Food. *https://vtechworks.lib.vt.edu/items/ec3a3514-638b-49a0-b8fc-b8ad4d37f91f* Date accessed July 5, 2024.

5. Fontana, A. J. Understanding the importance of water activity in food. *https://www.researchgate.net/publication/286871018_Understanding_the_importance_of_water_activity_in_food* Date accessed July 5, 2024.

Table 1. Water activity and growth of microorganisms in food.

Range of a_w	Microorganisms Generally Inhibited by Lowest a_w in this Range	Foods Generally in This Range
1.00–0.95	*Pseudomonas, Escherichia, Proteus, Shigella, Klebsiella, Bacillus, Clostridium perfringens*, some yeasts	Highly perishable (fresh) foods and canned fruits, vegetables, meat, fish, and milk; foods containing up to ≈40% (w/w) sucrose or 7% sodium chloride
0.95–0.91	*Salmonella, Vibrio parahaemolyticus, Clostridium botulinum, Serratia, Lactobacillus, Pediococcus*, some molds and yeasts	Some cheeses (cheddar, Swiss, muenster, provolone); cured meats; some fruit juice concentrates; foods containing 55% (w/w) sucrose or 12% sodium chloride
0.91–0.87	Many yeasts, *Micrococcus*	Fermented sausages; sponge cakes; dry cheeses; margarine; foods containing 65% (w/w) sucrose (saturated) or 15% sodium chloride
0.87–0.80	Most molds, *Staphylococcus aureus*, most *Saccharomyces* (bailii) spp., *Debaryomyces*	Most fruit juice concentrates; sweetened condensed milk; flour; rice; pulses containing 15–17% moisture
0.80–0.75	Most halophilic bacteria, mycotoxigenic aspergilli	Jam; marmalade
0.75–0.65	Xerophilic molds, *Saccharomyces bisporus*	Rolled oats containing ≈10% moisture; fudge; marshmallows; jelly; some dried fruits; nuts
0.65–0.60	Osmophilic yeasts, few molds	Dried fruits containing 15-20% moisture; honey
0.50	No microbial proliferation	Pasta containing ≈12% moisture; spices containing ≈10% moisture
0.40	No microbial proliferation	Whole egg powder containing ≈5% moisture
0.30	No microbial proliferation	Cookies, crackers, bread crusts, etc. containing 3–5% moisture
0.20	No microbial proliferation	Whole milk powder containing 2–3% moisture; dried vegetables containing ≈5% moisture; corn flakes containing ≈5% moisture

Source: Fontana, A. J. Understanding the importance of water activity in food (2000).

Another resource:

Blakeslee, Karen, and Castinado, Jaden. 2020. K-State Research and Extension Publication. Food Safety of Frostings and Fillings, *https://bookstore.ksre.ksu.edu/download/food-safety-of-frostings-and-fillings_MF3544*

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MF3674 September 2024