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APPLICATION NOTE

WATER ACTIVITY FOR
TOBACCO SAFETY AND
QUALITY



Like food products, tobacco products are vulnerable to quality and safety issues and therefore require well-designed product safety programs. Water activity plays a critical role in ensuring the safety and quality of intermediate- and low-moisture foods, and it offers the same protective benefits for tobacco products. Given the wide variety of tobacco products available, each can exhibit different water activity levels, which in turn correspond to varying degrees of risk and concern. Monitoring and managing water activity is thus essential for maintaining the integrity and safety of tobacco products throughout their shelf-life.

WATER ACTIVITY BASICS

Water activity is defined as the energy status of water in a system and is rooted in the fundamental laws of thermodynamics through Gibb's free energy equation. It represents the relative chemical potential energy of water as dictated by the surface, colligative, and capillary interactions in a matrix. As water interacts with other molecules through various interactions, a portion of the energy held in the bonds of the water molecule is transferred to the interaction, thereby lowering the energy of the water molecule itself. The more interactions provided to water by the product ingredients, the lower the energy of water will become. This lowering of the energy of water also reduces its capability to escape into the vapor phase causing a reduction in vapor pressure. A water activity of 0.50 indicates that the water in the product has 50% of the energy that pure water would have in the same situation. The lower the water activity, the less the water in the system behaves like pure water. Notice that the definition provided here never mentions the term 'free water' as this term is often mistakenly used to define water activity but has no scientific meaning.

WATER ACTIVITY MEASUREMENT

To test tobacco related products, water activity is measured by equilibrating the liquid phase water in the sample with the vapor phase water in the headspace of a closed chamber and measuring the Equilibrium Relative Humidity (ERH) in the headspace using a sensor. The relative humidity can be determined using a resistive electrolytic sensor, a chilled mirror sensor, a tunable diode laser (TDL), or a capacitive hygroscopic polymer sensor. Instruments from Novasina, like the Labmaster NEO, utilize a resistive electrolytic sensor (RES) to determine the ERH. Changes in ERH are tracked by changes in the electrical resistance of the electrolyte sensor. One of the primary challenges in testing tobacco products for water activity lies in the presence of numerous volatile compounds that contribute to tobacco's distinctive aroma. In January 2019, the Cooperation Centre for Scientific Research Relative to Tobacco (CORESTA) published Recommended Method No. 88, which specifies the use of Tunable Diode Laser (TDL) technology for water activity determination in tobacco. This method assumes that alternative technologies are ineffective due to interference from volatiles. While TDL is capable of handling such interference, it is costly and requires frequent maintenance. However, the Resistive Electrolytic Sensor (RES), when used with the eVALC protective filter, can accurately measure water activity in tobacco despite the presence of volatiles—an issue that affects chilled mirror and capacitancebased instruments. Comparative data (Table 1) show that RES provides results statistically equivalent to those of TDL. Thus, RES offers a reliable, low-maintenance, and cost-effective alternative for water activity testing in tobacco. These findings were presented to CORESTA in 2022 with a request to revise Method No. 88, but the organization declined to update the method.

Table 1. The water activity of 4 different Tobacco products measured by tunable diode laser and a resistive electrolytic sensor at 25 °C. The testing results were not significantly different from each other for any of the products as indicated by the P value from a paired t-test.

Tobacco Product	Resistive Electrolytic Sensor	Tunable Diode Laser	P Value
NP1	0.3894	0.3872	0.272
NP2	0.8175	0.8241	0.129
NP3	0.6346	0.6459	0.153
NP4	0.90685	0.8994	0.225

WATER ACTIVITY AND MICROBIAL GROWTH

For tobacco products, of greatest concern is microbial safety. They must be processed correctly to reduce the microbial load and prevent the subsequent proliferation of any microorganisms. Water activity controls microbial growth because it impacts their ability to reproduce and grow. When a microorganism encounters an environment where the water activity is lower than their internal water activity, they experience osmotic stress and begin to lose water to the environment as it moves to lower energy (1). This loss of water reduces turgor pressure and retards normal metabolic activity. To continue reproducing, the organism must lower its internal water activity below that of the environment so water will move back into the cell. It tries to achieve this by concentrating solutes internally. The ability to reduce its internal water activity using these strategies is unique to each organism. Consequently, each microorganism has a unique limiting water activity below which they cannot grow (1,2). A list of the water activity lower limits for growth for common spoilage organisms can be found in Table 2.

Table 2. WATER ACTIVITY SURVEY OF COMMON TYPES OF TOBACCO

Microorganism	aw limit	Microorganism	aw limit
Clostridium botulinum E	0.97	Penicillium expansum	0.83
Pseudomonas fluorescens	0.97	Penicillium islandicum	0.83
Escherichia coli	0.95	Debarymyces hansenii	0.83
Clostridium perfringens	0.95	Aspergillus fumigatus	0.82
Salmonella spp.	0.95	Penicillium cyclopium	0.81
Clostridium botulinum A B	0.94	Saccharomyces bailii	0.8
Vibrio parahaemolyticus	0.94	Penicillium martensii	0.79
Bacillus cereus	0.93	Aspergillus niger	0.77
Rhizopus nigricans	0.93	Aspergillus ochraceus	0.77
Listeria monocytogenes	0.92	Aspergillus restrictus	0.75
Bacillus subtilis	0.91	Aspergillus candidus	0.75
Staphylococcus aureus (anaerobic)	0.9	Eurotium chevalieri	0.71
Saccharomyces cerevisiae	0.9	Eurotium amstelodami	0.7
Candida	0.88	Zygosaccharomyces rouxii	0.62
Staphylococcus aureus (aerobic)	0.86	Monascus bisporus	0.61

WATER ACTIVITY AND MICROBIAL CONCERNS FOR TOBACCO

Because tobacco-related products exist in a wide variety of forms, they also exhibit a broad range of water activity levels, as shown in Table 1. As a result, the risk of microbial contamination and growth varies across different products. Table 2 highlights that tobacco products with water activity levels above 0.70 pose the greatest concern, as they are more likely to support microbial growth to potentially unsafe levels. Nevertheless, all tobacco products should undergo water activity analysis to assess their risk, and release specifications should be established accordingly to minimize microbial hazards. For products with water activity levels exceeding 0.70, additional control measures—such as temperature regulation, pH adjustment, or the use of preservatives—may be necessary to inhibit microbial growth. In such cases, the product safety program should include testing for all relevant controls, and release specifications should be aligned with these safety measures.

WATER ACTIVITY AND STORAGE STABILITY

Harvested tobacco must be adequately dried to ensure safe storage and transport. As previously discussed, water activity is a key factor in determining whether molds, yeasts, or bacteria can grow on biomass during storage. When dried tobacco bales are opened at a processing factory, they are very dry and will go through an initial softening process where they are exposed to 85% relative humidity. During this processing, the stems are removed, and any flavoring is added. The processed tobacco ready to be used in production typically falls within a water activity range of 0.60 to 0.70 aw and must be stored under controlled humidity to maintain this desired water activity range. While pathogenic bacteria pose the greatest risk in fresh biomass with higher water activity, the primary concern in processed tobacco is mold contamination. Most molds cease to grow below 0.70 aw, with only a few rare xerophilic species capable of surviving at lower levels. Although molds themselves are not highly toxic when consumed, they can produce harmful mycotoxins that may trigger severe reactions in sensitive individuals. Additionally, the presence of active mold growth indicates the presence of mold spores, which is particularly concerning for inhaled products like tobacco. Inhalation of mold spores can lead to respiratory issues, including asthma symptoms. Therefore, it is critical that the water activity of harvested biomass intended for storage or transport remains below 0.70 aw. This underscores the importance of initiating water activity testing at the cultivation and processing stages.

WATER ACTIVITY AND TOBACCO PRODUCTION

Controlling water activity during the production of tobacco products is essential to avoid process disruptions and material waste. For instance, filter rods used in cigarette manufacturing must maintain a water activity of at least 0.50 aw to prevent static electricity buildup, which can cause the rods to stick together. Additionally, consistent water activity must be preserved while the material is still in roll form to prevent tearing, feeding errors, and refeeding—issues that lead to costly downtime. Once the tobacco and filter rod are combined, their water activities should be closely matched to prevent moisture migration. Imbalances can cause the filter material to shrink or tear and may increase the risk of microbial growth in the tobacco.

PHYSICAL STABILITY

The shelf life of tobacco products depends not only on ensuring safety but also on preserving key quality attributes such as texture and smoking performance. For products with water activity levels below 0.70 aw, chemical degradation becomes the primary concern, potentially altering the smoking experience. These degradative reactions—typically oxidation or hydrolysis—are strongly influenced by both temperature and water activity. Therefore, the optimal strategy is to identify a water activity level that minimizes the rate of these chemical reactions while still maintaining the desired texture profile. Striking this balance is essential for maximizing both the longevity and quality of tobacco products. To determine the optimal water activity level for minimizing chemical degradation in tobacco products, shelf life models can be employed to predict reaction rates. For these models to be effective, they must incorporate both water activity and temperature as key variables. The only fundamental model that does so is the hygrothermal time model, which is based on a modified form of the Eyring equation for reaction rate and the Gibbs free energy equation. The model is expressed as:

$$r = r_0 \exp \left(Ba_w - \frac{E_a}{RT} \right)$$

where:

- T is the temperature (K),
- R is the gas constant (J·mol⁻¹·K⁻¹),
- Ea is the activation energy (J·mol⁻¹),
- B is the molecular volume ratio,
- aw is the water activity
- r₀ is the rate at the standard state.

In practice, the constants B, Ea/R, and r₀ are determined empirically through least squares regression. Once these parameters are known, the model can be used to predict the rate of chemical change under any combination of temperature and water activity. This allows for the identification of an ideal water activity level that minimizes chemical degradation, thereby extending the shelf life of tobacco products. Achieving and maintaining this ideal water activity— one that prevents microbial growth while also reducing chemical and textural degradation— is key to maximizing product stability and quality. Another key quality attribute of tobacco products is texture. When tobacco becomes overdried, it turns brittle and prone to breakage, which can lead to the loss of essential volatile compounds that contribute to smoking quality. This brittleness also complicates the processing of raw tobacco into finished products, often resulting in increased product rejection rates. Conversely, in dry smokeless tobacco products, elevated water activity levels—typically above 0.50 aw—can lead to caking and clumping, negatively affecting product appearance and usability. To determine the ideal water activity for maintaining optimal texture, it may be necessary to condition tobacco at various water activity levels and evaluate the effects on appearance, taste, and smoking performance.

CONCLUSION

In conclusion, water activity is a fundamental factor in ensuring both the safety and quality of tobacco products. It serves as a critical control point in product safety programs and is essential for meeting regulatory requirements. Beyond safety, identifying the ideal water activity level that minimizes chemical degradation while preserving the desired texture is key to maintaining customer-perceived quality. Novasina's resistive electrolytic water activity instruments, when equipped with the eVALC protective filter, offer a precise, reliable, and cost-effective alternative to TDL technology for measuring water activity in tobacco products.



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