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APPLICATION NOTE

THE ROLE OF WATER ACTIVITY TESTING IN WINE PRODUCTION AND STORAGE

The wine industry is a vast and dynamic global market, encompassing everything from small, family-owned vineyards to large multinational corporations. As of recent years, the industry has been valued at over $300 billion, with key production regions including France, Italy, Spain, the United States, and Australia. Wine production involves a complex supply chain, from grape cultivation and fermentation to distribution and retail sales. The industry is also shaped by consumer preferences, trends such as organic and sustainable winemaking, and technological advancements in viticulture and distribution.

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As with any food or beverage product, the safety, quality and shelf-life of wine are of upmost importance. Water activity has been proven to play a critical role in product safety and quality for intermediate and low moisture foods. While the water activity of wine itself tends to be quite high, water activity still plays a role in maintaining its quality and safety during both production and storage.

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 through the addition of polar molecules such as sugar, 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 wine or wine 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, or a capacitive hygroscopic polymer sensor. Instruments from Novasina, like the Labmaster NEO, utilize an electrolytic sensor to determine the ERH. Changes in ERH are tracked by changes in the electrical resistance of the electrolyte sensor. The advantage of this approach is that it can measure the water activity of alcohol containing samples while the alcohol will interfere with chilled mirror or capacitance based instruments. The resistive electrolytic sensor can achieve the highest level of accuracy and precision with no maintenance and infrequent calibration.

WATER ACTIVITY AND MICROBIAL GROWTH

For all food and beverage products, of greatest concern is the microbial safety of these products. 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 1.

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

Microorganism	a_w limit	Microorganism	a_w limit
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	0.8
Vibrio parahaemoliticus	0.94	Penicillum martensii	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)	0.9	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

MICROBIAL CONCERNS FOR WINE

The water activity levels of wine vary depending on the variety, as shown in Table 2. A comparison between Tables 1 and 2 suggests that wine could be susceptible to microbial growth. However, the combination of low pH, high alcohol content, and controlled water activity is sufficient to prevent microbial proliferation during storage (3). Interestingly, water activity control plays a more critical role in cork safety. If moisture migration from the wine raises the cork's water activity above the mold growth threshold, mold could develop, making the wine undesirable to consumers. To prevent this, corks should be manufactured with sufficiently low water activity before installation, and the portion exposed to the environment must remain below the mold growth limit.

Water activity control is also essential for promoting the growth of beneficial microorganisms in wine production. Yeasts used during fermentation require precise water activity regulation to optimize their growth while suppressing harmful pathogenic bacteria. Optimizing yeast fermentation then necessitates tight control of water activity during the fermentation period.

Another example of a beneficial microorganism in wine is **Botrytis cinerea**, known as noble rot, which is necessary for the proper production of certain wines (4). When present on ripening grapes, it enhances sugar, acid, and flavor concentration. For this application, the skin of grape is cut off and tested for water activity. By taking cuttings from grapes at different time periods during maturation, it is possible to create an index that determines if harvest needs to be initiated earlier. If harvest is not timed with the ideal water activity index, the infection can progress into gray rot, which is undesirable.

Lastly, in wine cellars, the growth of **Cladosporium cellare**, sometimes called noble mold, is encouraged, as it helps stabilize humidity and temperature fluctuations. In this case, the presence of the mold, while considered detrimental in other buildings, is desirable for wine storage and is encouraged.

Table 2. Water activity survey of common types of wines.

Product	Water Activity (a_w)
Dry Wines	0.96-0.99
Sweet Wines	0.86-0.95
Fortified Wines	0.90-0.98

WINE QUALITY AND GRAPE HARVEST

The timing of grape harvest is crucial for producing high-quality wine. Harvesting too early can result in insufficient sugar levels, while harvesting too late may lead to fruit breakdown. To optimize harvest timing, wine grape producers continuously seek better methods. One such approach involves tracking changes in grape water activity throughout ripening and then harvesting when a predetermined water activity level is reached. Since water activity declines as sugar concentration increases, establishing a correlation between ideal sugar levels and a critical water activity threshold allows for precise harvest timing. During this critical ripening stage, daily grape sampling for water activity testing ensures optimal conditions for wine production.

CONCLUSION

In conclusion, water activity plays a fundamental role in both wine production and storage. While wine itself is generally protected from microbial growth due to its low pH and high alcohol content, controlling water activity is crucial for maintaining cork integrity and preventing mold contamination. Additionally, water activity regulation supports the growth of beneficial microorganisms during fermentation and influences the development of noble rot, which enhances certain wine varieties. Furthermore, monitoring water activity during grape ripening provides a valuable tool for optimizing harvest timing and ensuring high-quality wine. By understanding and managing water activity, winemakers can enhance both the safety and excellence of their final product

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Dr. Brady Carter is a Senior Research Scientist with Carter Scientific Solutions. He specializes in Water Activity and Moisture Sorption applications. Dr. Carter earned his Ph.D. and M.S Degree in Food Engineering and Crop Science from Washington State University and a B.A. Degree in Botany from Weber State University. He has 20 years of experience in research and development and prior to starting his own company, he held positions at Decagon Devices and Washington State University. Dr. Carter currently provides contract scientific support to Novasina AG and Netuec Group. He has been the instructor for water activity seminars in over 23 different countries and has provided on-site water activity training for companies around the world. He has authored over 20 white papers on water activity, moisture sorption isotherms, and complete moisture analysis. He has participated in hundreds of extension presentations andhas given talks at numerous scientific conferences. He developed the shelflife simplified paradigm and hygrothermal time shelf life model.

REFERENCES
1. Beuchat, L. 1983. Influence of water activity on growth, metabolic activities and survival of yeasts and molds. Journal of Food Protection 46(2):135-141.
2. Scott, W. 1957. Water relations of food spoilage microorganisms. Advances in Food Research 7:83-127.
3. Leistner, L. 1985. Hurdle technology applied to meat products of the shelf stable product and intermediate moisture food types. In Properties of Water in Foods pg. 309-329. Martinus Nijhoff Publishers, Boston, MA.
4. Marie André. Evaluation of the fragility of the grape skin in the Champagne context. Chemistry Analytical. University of Bordeaux, 2021. French. ffNNT: 2021BORD0360ff. fftel-04368902f

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