Analyzing the Effects of Humidity on Portable Dehumidifier Efficiency

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Abstract

Analyzing Factors that Affect a Portable Vapor Compression Dehumidifier's Efficiency (Measured in L/kWh). This research paper is sponsored by the National Institute of Standards and Technology. The purpose of this study is to determine factors that affect portable vapor compression dehumidifier efficiency. This research aims to discover to what extent does exterior weather influence the efficiency and cycling of portable dehumidification systems. In this quantitative case study analysis we looked at a dehumidifier and used sensors to measure weather conditions and the dehumidifier energy usage. We used ambient weather sensors and put the data into a CSV and then used Python and Matplotlib and Pandas to do the analysis. In conclusion the study found a positive correlation between absolute and relative humidity and efficiency. More tests would need to occur with multiple dehumidifiers in the same weather conditions but in different houses to validate the data.

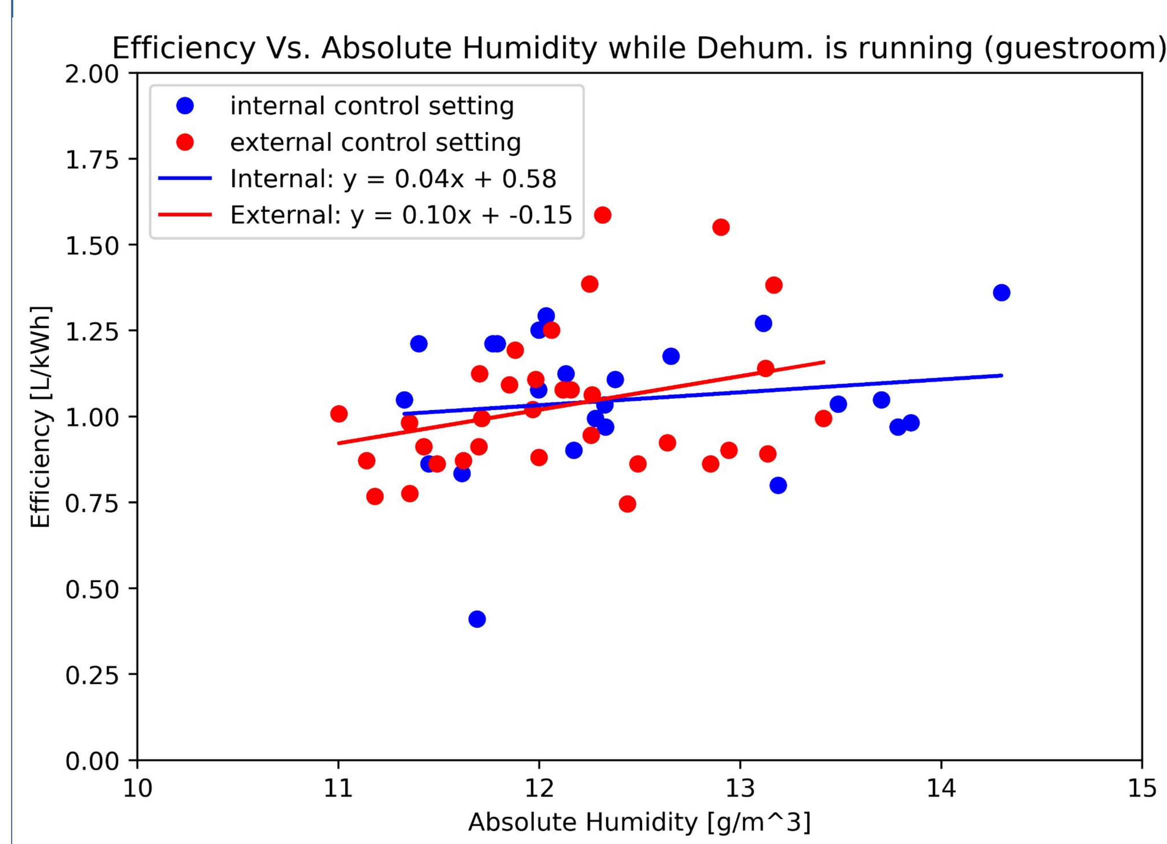
Major Research in the Field

- Ybyraiymkul et.al. (2023): Explored distributed microwaves for dehumidification.
  - Efficiency: Microwave systems demonstrated efficient power usage (97–99.5%).
- NIST and Lawrence Berkeley National Laboratory: Human comfort at 50%, ideal range 45-55%.
  - Different Standards for Pools: 40-80% ideal, with 50-60% preventing the growth of fungi, bacteria, and viruses.
  - Trade-off: Balancing energy efficiency and human comfort is challenging.
- Islam et al. (2023): Portable dehumidifiers improve overall humidity and seasonal yields.
  - Portable Dehumidifiers in Greenhouses: Introduced for maintaining uniform humidity levels.
- Willem (2013): Relationship between compressor run time and outdoor humidity.
  - Dehumidifier Efficiency: Cycling on and off affects efficiency due to energy loss.
  - Seasonal Usage: Peak usage in July and August, little usage in fall, winter, and early spring.

Methods and Materials

- Follows experimental design to observe dehumidifier performance in various weather conditions.
- Quantitative research to test weather impact on dehumidifier efficiency (Creswell, 2021).
- Dehumidifier Model:
  - Studied Frigidaire's model FFAD5033W1 portable vapor compression dehumidifier.
  - Rated for 1.80 kWh, 2.1 gallons bucket capacity, 50 pints per day dehumidification, 35-85% relative humidity range.
- Used Python with ambient weather and NetZero code data for plotting and interpolation.
- Matplotlib used for plotting, including dehumidifier outlet temperature charts.

Data

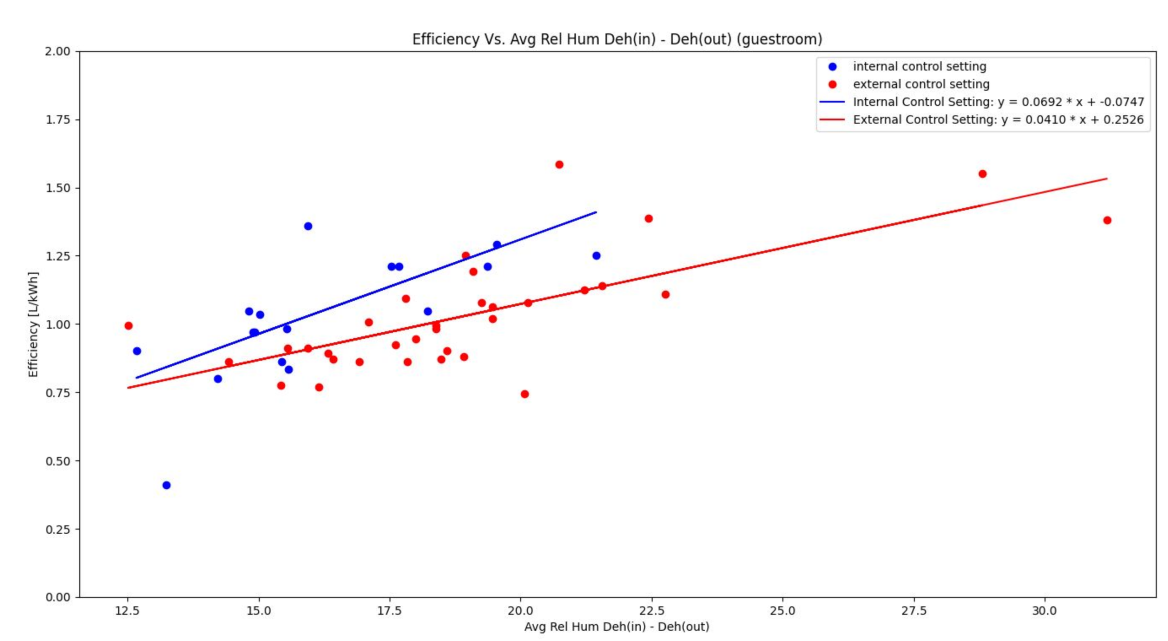


Most data clusters between 0.75 and 1.25 L/kWh efficiency and an absolute humidity of 11 to 14 g/m^3.

Internal control setting: P-value (Prob F-statistic) of 0.456516.

External control sensor: P-value of 0.088353

External control setting has a P-value for Avg Abs Hum < 0.05, indicating statistical significance.



External control setting: P-value of 3.46e−06.

Internal control setting: P-value of 0.000295.

Both below 0.05, indicating statistical significance.

Larger relative humidity difference correlates with higher efficiency.

Outlet humidity tends to remain constant, suggesting the inlet relative humidity may indicate efficiency.

Findings

The data shows that, contrary to expectations, higher humidity doesn't necessarily reduce dehumidifier efficiency. Even with elevated humidity, the efficiency remains high, indicating that the tank doesn't fill up fully. This suggests a nuanced connection between dehumidifier location and efficiency, optimizing for extended runtimes without compromising effectiveness.

Variable	Averaged During Runtime	Sensor Location	Control Setting	P-Value	Equation for Efficiency	Statistically Significant (by P-Value)
Absolute Humidity [g/m^3]	Yes	Guestroom	Internal Control Sensor	0.456516	= 0.04(Avg Abs Hum) + 0.58	No
Absolute Humidity [g/m^3]	Yes	Guestroom	External Control Sensor	0.088353	= 0.10 × (Avg Abs Hum) + -0.15	Yes
Rel Hum(Deh(in) - Deh(out))	Yes	Dehum. Inlet & Dehum. Outlet	Internal Control Sensor	0.000295	= 0.0692 × (Avg Rel Hum Deh(in) - Deh(out)) − 0.0747	Yes
Rel Hum(Deh(in) - Deh(out))	Yes	Dehum. Inlet & Dehum. Outlet	External Control Sensor	3.46e−06	= 0.0410 × (Avg Rel Hum Deh(in) - Deh(out)) + 0.2526	Yes

Limitations and Future Research

- Limited Inlet and Outlet Sensor Data: The research acknowledges a limitation in the available data for the inlet and outlet sensors, indicating that additional data in this aspect could enhance the understanding of dehumidifier runtime.
- Working Towards Solutions: The research acknowledges that identifying current constraints is a stepping stone towards finding solutions. While the study highlights existing limitations, it emphasizes the potential for addressing these challenges in subsequent research endeavors.

Appreciation and Final Thoughts

- A heartfelt thank you to Dr. Gregory Linteris for his invaluable mentorship during this research. His expertise and support have been crucial in shaping the study's direction, and his commitment to excellence has enriched my learning experience.
- Gratitude extends to the National Institute of Standards and Technology (NIST) for fostering an environment of innovation. The resources and collaborative spirit at NIST have played a pivotal role in the success of this research. This experience will undoubtedly leave a lasting impact on my academic and professional journey.
- Thanks to my mentor Dr. Gregory Linteris!

References

Brown, P. J., & DeGaetano, A. T. (2013). Trends in U.S. surface humidity, 1930–2010. *Journal of Applied Meteorology and Climatology,* 52(1), 147-163. https://doi.org/10.1175/jamc-d-12-035.1

Barreca, A. I. (2012). Climate change, humidity, and mortality in the United states. *Journal of Environmental Economics and Management*, 63(1), 19-34. https://doi.org/10.1016/j.jeem.2011.07.004

Campen, J., Bot, G., & de Zwart, H. (2003). Dehumidification of greenhouses at northern latitudes. *Biosystems Engineering*, 86(4), 487-493. https://doi.org/10.1016/j.biosystemseng.2003.08.008

Cobo-Golpe, M., Ramil, M., Cela, R., & Rodríguez, I. (2020). Portable dehumidifiers condensed water: A novel matrix for the screening of semi-volatile compounds in indoor air. Chemosphere, 251, 126346. https://doi.org/10.1016/j.chemosphere.2020.126346

Creswell, J. W., & Creswell, J. D. (2021). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). SAGE Publications.

Dehumidifiers Key Efficiency Criteria. (n.d.). Energystar.gov. https://www.energystar.gov/products/dehumidifiers/key_efficiency_criteria

Energy conservation program: Energy conservation standards for dehumidifiers. (2016). Federal Information & News Dispatch.

Willem, H. (2013). Field-Metered data from portable unit dehumidifiers in the U.S. residential sector: Initial results of a pilot study. Retrieved from https://doi.org/10.2172/1172130.

Islam, M. N., Md Zafar Iqbal, Ali, M., Gulandaz, M. A., Md Shaha Nur Kabir, Seung-Ho, J., & Sun-Ok, C. (2023). Evaluation of a 0.7 kW suspension-type dehumidifier module in a closed chamber and in a small greenhouse. Sustainability, 15(6), 5236. https://doi.org/10.3390/su15065236

Jain, S., Tripathi, S., & Das, R. S. (2011). Experimental performance of a liquid desiccant dehumidification system under tropical climates. *Energy Conversion and Management*, 52(6), 2461-2466. https://doi.org/10.1016/j.enconman.2010.12.052

Li, Y., Lu, L., & Yang, H. (2010). Energy and economic performance analysis of an open cycle solar desiccant dehumidification air-conditioning system for application in hong kong. *Solar Energy*, 84(12), 2085-2095. https://doi.org/10.1016/j.solener.2010.09.006

Nauta, A., Han, J., Syeda, H. T., & Lubitz, W. D. (2023). Performance evaluation of a commercial greenhouse in canada using dehumidification technologies and LED lighting: A modeling study. *Energies*, 16(3), 1015. https://doi.org/10.3390/en16031015

Payne W. V. (2016). Annual Performance of a Two-Speed, Dedicated Dehumidification Heat Pump in the NIST Net-Zero Energy Residential Test Facility. ASHRAE winter conference papers. American Society of Heating, Refrigeration and Air-Conditioning Engineers, *2016 ASHRAE Winter Conference*, OR-16-C040.

Rahman, M. S., Han, J., Ge, G., Ahamed, M. S., & Guo, H. (2023). Experimental evaluation of three different dehumidifiers for greenhouses in cold regions. *Applied Thermal Engineering*, 234, 121324. https://doi.org/10.1016/j.applthermaleng.2023.121324

Santos, A. F., Gaspar, P. D., Heraldo J L de Souza, João M L P Caldeira, & Vasco N G J Soares. (2023). An Eco-Energetic Performance Comparison of Dehumidification Systems in High-Moisture Indoor Environments. *Applied Sciences*, 13(11), 6824. https://doi.org/10.3390/app13116824

Willem, H. (2013). *Using Field-Metered Data to Quantify Annual Energy Use of Residential Portable Unit Dehumidifiers*. Energy Efficiency Standards Group, Energy Analysis and Environmental Impacts Division.

Ybyraiymkul, D., Chen, Q., Burhan, M., Akhtar, F. H., AlRowais, R., Shahzad, M. W., Ja, M. K., & Ng, K. C. (2023). Innovative solid desiccant dehumidification using distributed microwaves. *Scientific Reports* (Nature Publisher Group), 13(1), 7386. https://doi.org/10.1038/s41598-023-34542-9

Islam, M. N., Md Zafar Iqbal, Ali, M., Gulandaz, M. A., Md Shaha Nur Kabir, Seung-Ho, J., & Sun-Ok, C. (2023). Evaluation of a 0.7 kW suspension-type dehumidifier module in a closed chamber and in a small greenhouse. Sustainability, 15(6), 5236. https://doi.org/10.3390/su15065236

Jain, S., Tripathi, S., & Das, R. S. (2011). Experimental performance of a liquid desiccant dehumidification system under tropical climates. *Energy Conversion and Management*, 52(6), 2461-2466. https://doi.org/10.1016/j.enconman.2010.12.052

Li, Y., Lu, L., & Yang, H. (2010). Energy and economic performance analysis of an open cycle solar desiccant dehumidification air-conditioning system for application in hong kong. *Solar Energy*, 84(12), 2085-2095. https://doi.org/10.1016/j.solener.2010.09.006

Nauta, A., Han, J., Syeda, H. T., & Lubitz, W. D. (2023). Performance evaluation of a commercial greenhouse in canada using dehumidification technologies and LED lighting: A modeling study. *Energies*, 16(3), 1015. https://doi.org/10.3390/en16031015

Payne W. V. (2016). Annual Performance of a Two-Speed, Dedicated Dehumidification Heat Pump in the NIST Net-Zero Energy Residential Test Facility. ASHRAE winter conference papers. American Society of Heating, Refrigeration and Air-Conditioning Engineers, *2016 ASHRAE Winter Conference*, OR-16-C040.

Rahman, M. S., Han, J., Ge, G., Ahamed, M. S., & Guo, H. (2023). Experimental evaluation of three different dehumidifiers for greenhouses in cold regions. *Applied Thermal Engineering*, 234, 121324. https://doi.org/10.1016/j.applthermaleng.2023.121324

Santos, A. F., Gaspar, P. D., Heraldo J L de Souza, João M L P Caldeira, & Vasco N G J Soares. (2023). An Eco-Energetic Performance Comparison of Dehumidification Systems in High-Moisture Indoor Environments. *Applied Sciences*, 13(11), 6824. https://doi.org/10.3390/app13116824

Willem, H. (2013). *Using Field-Metered Data to Quantify Annual Energy Use of Residential Portable Unit Dehumidifiers*. Energy Efficiency Standards Group, Energy Analysis and Environmental Impacts Division.

Ybyraiymkul, D., Chen, Q., Burhan, M., Akhtar, F. H., AlRowais, R., Shahzad, M. W., Ja, M. K., & Ng, K. C. (2023). Innovative solid desiccant dehumidification using distributed microwaves. *Scientific Reports* (Nature Publisher Group), 13(1), 7386. https://doi.org/10.1038/s41598-023-34542-9