Contribution ID: **88** Type: **Poster**

The role of proteins in controlling evaporation and hygroscopic behavior of exhaled respiratory droplet

Background and Objective:
The transmission of respiratory pathogens via exhaled droplets and aerosols is a key mechanism in the spread of infectious diseases such as influenza and COVID-19. The physicochemical properties of exhaled respiratory droplets, which vary under different environmental conditions, directly influence the survival and transport of airborne pathogens. Factors such as temperature, relative humidity (RH), sunlight, and pH play crucial roles in determining pathogen activity. Among these, RH has been shown to significantly impact pathogen activity in respiratory droplets; however, the underlying mechanisms remain unclear, particularly given the complex composition of respiratory droplets. A deeper understanding of the physicochemical properties of exhaled respiratory droplets is essential for comprehending the spread of airborne diseases and predicting aerosol transmission dynamics. In this study, we investigate the role of mucin and albumin, key respiratory proteins, in controlling droplet evaporation and hygroscopic behavior, with the aim of better understanding RH-dependent pathogen activity within respiratory droplets.
Methods:
An electrodynamic balance (EDB) was used to levitate individual droplets under RH conditions ranging from $<$ 5% to 97%. This setup prevented the droplets from contacting any surface, enabling measurements of their evaporation and the hygroscopic growth. Changes in droplet mass and size were measured using the two-dimensional light scattering patterns recorded during the experiment. The morphology and chemical composition of droplets in their equilibrium state were analyzed using an environmental scanning electron microscope (ESEM) equipped with an energy-dispersive X-ray (EDX) spectrometer, with 50 Pa N2 as the background gas.
Results:
Our results show that the presence of mucin affected the evaporation and the rehydration of the respiratory droplets. Specifically, mucin was found to slightly retard the evaporation process, which is likely due to the formation of a semi-solid layer on the surface of the droplets during evaporation. This layer appears to impede the uptake of water, thus influencing the hygroscopic growth behavior of the droplets. While the results for mucin are conclusive, data analysis for albumin is still ongoing, and further insights into its role in droplet behavior will be presented once the analysis is completed. However, SEM images suggest that , unlike mucin, albumin does not form a dense outer shell under dry conditions, highlighting a distinct difference in the behavior of these two proteins.
Conclusion:
Our results highlight the significant role of different proteins in affecting the properties of exhaled respiratory droplets during evaporation and rehydration. The organic content of respiratory fluids varies depending on the region of the respiratory tract where it is produced. Virus-laden respiratory droplets generated in areas with higher organic content may form a more robust shell under dry conditions, thereby enhancing the virus's environmental survivability by protecting it from factors such as temperature, humidity, and ultraviolet radiation. The variation in the physicochemical properties and morphology of respiratory droplets, especially in the presence of different organic compounds and varying organic content, remains an area worthy of further exploration and should be the focus of future research.

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