Investigating apple surface condensation and mass loss with IoT sensors and predictive modelling

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XIV International Controlled and Modified Atmosphere Research Conference (CAMA 2025)
Washington, 18-22 May 2025, https://cama2025.com/

This study analysed condensation and mass loss on apple surfaces using IoT-based sensors and predictive modelling in storage. The condensation model was developed based on the mass transfer coefficient, which was determined using the Sherwood number. The mass loss model accounts for transpiration and respiration of apple. Both models work in tandem to predict the real-time cumulative condensation, condensation retention time, cumulative mass loss and in the end mass of apples in storage. The model was validated using experiments under low (4.2-6.3°C) and high (2.7-8.3°C) temperature fluctuations in apple storage. Real-time data in air and on apple surface temperature, humidity, air velocity, and surface wetness were collected via different sensors. All sensors collected data, which was sent to the Raspberry Pi and forwarded to Kafka for processing and predictions. Then, data were stored in InfluxDB for graphical visualisation. The IoT model effectively predicted condensation, retention time, and mass loss, aligning with the trends of experimental values in both low and high-temperature fluctuations. For low fluctuations, the peak predicted cumulative condensation was 0.03 g kg-1 of apple surface area, approximately half the experimental peak of 0.1 g kg-1, with a mass loss of 0.9 g kg-1 of apples over 2.5 days primarily due to transpiration. For high fluctuations, the predicted peak reached 1.1 g kg-1 compared to the experimental peak of 1.8 g kg-1, with a corresponding mass loss of 0.8 g kg-1 of apples over 2.5 days, also attributed mainly to transpiration. The temperature fluctuations significantly affected condensation and mass loss in apples, with high fluctuations leading to much greater cumulative condensation compared to low fluctuations. However, the experimental values of peak cumulative condensation were consistently higher than the predicted ones, likely due to limitations in sensor accuracy, the complexity of the experimental setup, and the theoretical model used for predictions. Moreover, larger condensation retention time (53.8% of total time) in high fluctuations caused less apple mass loss compared to low fluctuations (10.6%).