Tropentag, September 14-16, 2022, hybrid conference

"Can agroecological farming feed the world?
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Mathematical model to predict and simulate bulk tomatoes temperature stored in a nature-assisted low-cost-low-temperature storage structure for rift valley production area in Ethiopia

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Abstract

Ethiopia, especially the rift valley region, is home to produce wide range of fruits and vegetables to the central market. Despite high production the after harvest loss of fruits and vegetables due to absence of cooling room facilities is high. Use of commercially available mechanical refrigeration system is expensive and cannot be afforded by local farmers. This work conducted with the aim of developing a mathematical model and simulation to predict product temperature after employing combined use of three natures assisted cooling methods (day time Evaporative cooling (EC), Night time ventilation (NV) and use of high thermal mass materials). A 3D time-dependent heat transfer in the moist air interface in COMSOL Multiphysics is employed to develop the model that predicts and simulates tomatoes' temperature stored in a low-cost low-temperature storage structure that combines that above cooling principles. The EC cooling systems operating during the daytime and the NV cooling systems running at night were simulated and modeled. The construction materials for the storage structure were high thermal mass materials. Simulation results indicate that, in the daytime, employing an EC system for 10 hours provides a 9.65K reduction in product temperature from an ambient temperature. Additionally, utilising the NV cooling system (when night time air temperature cooler than storage room temperature) in tandem with high thermal mass materials for 8 hours enables to maintain the product temperature, assisted by the daytime EC system (298K). Gradually the product temperature is reduced by about 4.1K when the nighttime ambient temperature cooler than the product temperature inside the cold storage. Generally, employing EC and NV cooling systems with the assistance of high thermal mass material enables to create and maintain product temperature at least 10oK as compared to the ambient. Based upon the Q10 concept this much temperature reduction could doubles the storage time of the fruit as compare to fruits stored in ambient temperature.

Keywords: Evaporative cooling, nighttime ventilation, thermal mass, tomatoes

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